2010 NUTRIENTS AND SUSPENDED SEDIMENT IN THE SUSQUEHANNA RIVER BASIN

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SUSQUEHANNA RIVER BASIN COMMISSION

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**Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).*

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ABSTRACT

In 1985, the Susquehanna River Basin Commission (SRBC) along with the United States Geological Survey (USGS), the Pennsylvania Department of Environmental Protection (PADEP), and United States Environmental Protection Agency (USEPA) began an intensive study of nutrient and sediment transport in the Susquehanna River Basin. Funding for the program was provided by grants from the PADEP and the USEPA's Chesapeake Bay Program Office. The long-term focus of the project was to quantify the amount of nutrients and suspended sediment (SS) transported in the basin and determine changes in flow-adjusted concentration trends at twelve sites. Several modifications were made to the network including reducing the original twelve sites to six long-term sites then adding 13 sites in 2004 and four sites in 2005. The current network consists of 23 sites throughout the Susquehanna River Basin varying in watershed size and land use.

Samples were collected monthly with eight additional samples collected during four storm events throughout the year. An extra sample was collected each month at the six long-term sites including Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga. Sample collection was conducted using approved USGS methods including vertical and horizontal integration across the water column to insure collection of a representative sample. Samples were analyzed for various nitrogen and phosphorus species, total organic carbon (TOC), total suspended solids (TSS), and SS. Data were used to calculate nutrient and sediment loads and trends using the USGS estimator model. Results for annual, seasonal, and monthly loads were compared to long-term means (LTM) and to baseline data. Trends for all parameters and flow were calculated over the entire time period for each dataset and compared to previous years' results to identify changes.

2010 precipitation was dominated by four major rainfall events during the winter months of January and March and the fall months of October and December. The March event was a nor'easter and the other three were Maddox Synoptic type events (Maddox et al., 1979). During the months containing these storms, between 62-64 percent of the annual TN load, 69-77 percent of the annual TP load, and 83-91 percent of the annual SS load were transported.

All comparisons of 2010 yields to initial baseline data showed improvements. Additionally, comparisons of baselines created from the first half of each dataset and baselines created from the second half have consistently shown that nutrient and SS levels have decreased between these two periods. Comparison of both periods to the initial five-year dataset at each site showed that there were larger improvements early on in the data period and that the rate of improvements reduced somewhere in the middle of the period.

Consistent, basinwide trend results at all sites include downward trends for TN, DN, TON, DON, and SS. Other common trends included downward trends for TP at all sites except Towanda, and downward for TOC at all sites except Lewisburg. Unique findings included no trend for DP at both Towanda and Danville and upward trends for DOP at Towanda and Newport. Conestoga was the only site to have downward trends for all phosphorus species. This report discusses the findings from the Susquehanna Nutrient Assessment Program for the calendar year 2010.

BACKGROUND

Nutrients and SS entering the Chesapeake Bay (Bay) from the Susquehanna River Basin contribute to nutrient enrichment problems in the Bay (USEPA, 1982). Several studies in the late 1970s and early 1980s showed high nutrient concentration in both stream water and groundwater and high SS yields within the Lower Susquehanna River Basin (Ott et al., 1991). Subsequently, much of the excessive nutrient and SS that entered the Bay were thought to originate from the lower Susquehanna basin. Results from these studies concluded that the sources and quantities of the loads warranted determination. In 1985, the PADEP Bureau of Laboratories, USEPA, USGS, and SRBC conducted a five-year study to quantify nutrient and SS transported to the Bay from the Susquehanna River Basin.

The initial network consisted of two mainstem sites on the Susquehanna and 10 tributary sites with the goal of developing baseline nutrient loading data. After 1989, several modifications to the network occurred, including reduction of the number of stations to five in 1990, addition of one station in 1994, addition of 13 stations in 2004, and addition of three stations in 2005. The current network consists of six sites on the mainstem of the Susquehanna River and 17 tributary sites, with nine sites being part of the original study network. Four additional tributary sites will be added in 2012, making the total network 27 sites, with six in New York, 20 in Pennsylvania, and one in Maryland. Table 1 lists the individual sites grouped as long-term sites (Group A) and enhanced sites (Group B) along with subbasin, drainage area, USGS gage number, and land use. Actual locations of current and future sites are shown in Figure 1.

All site additions from 2004 onward were added as part of the Chesapeake Bay Program's Non-tidal Water Quality Monitoring Workgroup's effort to develop a non-tidal monitoring network uniform in site selection criteria, parameters analyzed, and collection and analysis methodology. Anticipated objectives for the network included the following: to measure and assess the actual nutrient and sediment concentration and load reductions in the tributary strategy basins across the watershed; to improve calibration and verification of the partners' watershed models; and to help assess the factors affecting nutrient and sediment distributions and trends. Specific site selection criteria included location at outlets of major streams draining the tributary strategy basins, location in areas within the tributary strategy basins that have the highest nutrient delivery to the Bay, and to insure adequate representation of the various conditions in the Bay watershed among land use type, physiographic/geologic setting, and watershed size. This project involves monitoring efforts conducted by all six Bay state jurisdictions, USEPA, USGS, and SRBC. The purpose of this report is to present basic information on annual and seasonal loads and yields of nutrients and SS measured during calendar year 2010 at the six SRBC-monitored long-term sites, summary statistics for the additional 17 sites, and to determine if changes in water quality have occurred.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River drains an area of 27,510 square miles (Susquehanna River Basin Study Coordination Committee, 1970), and is the largest tributary to the Chesapeake Bay. The Susquehanna River originates in the Appalachian Plateau of southcentral New York, flows into the Valley and Ridge and Piedmont Provinces of Pennsylvania and Maryland, and joins the Bay at Havre de Grace, Md. The climate in the Susquehanna River Basin varies considerably from the low lands adjacent to the Bay in Maryland to the high elevations, above 2,000 feet, of the northern headwaters in central New York State. The annual mean temperature ranges from 53° F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45° F in the northern part of the basin. Annual precipitation in the basin averages 39.15 inches and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin, shown in Table 1, is predominantly rural with woodland accounting for 69 percent; agriculture, 21 percent; and urban, 7 percent. Woodland occupies the higher elevations of the northern and western parts of the basin and much of the mountain and ridge land in the Juniata and Lower Susquehanna Subbasins. Woods and grasslands occupy areas in the lower part of the basin that are unsuitable for cultivation because the slopes are too steep, the soils are too stony, or the soils are poorly drained. The Lower Susquehanna Subbasin contains the highest density of agriculture operations within the watershed. However, extensive areas are cultivated along the river valleys in southern New York and along the West Branch Susquehanna River from Northumberland, Pa., to Lock Haven, Pa., including the Bald Eagle Creek Valley.

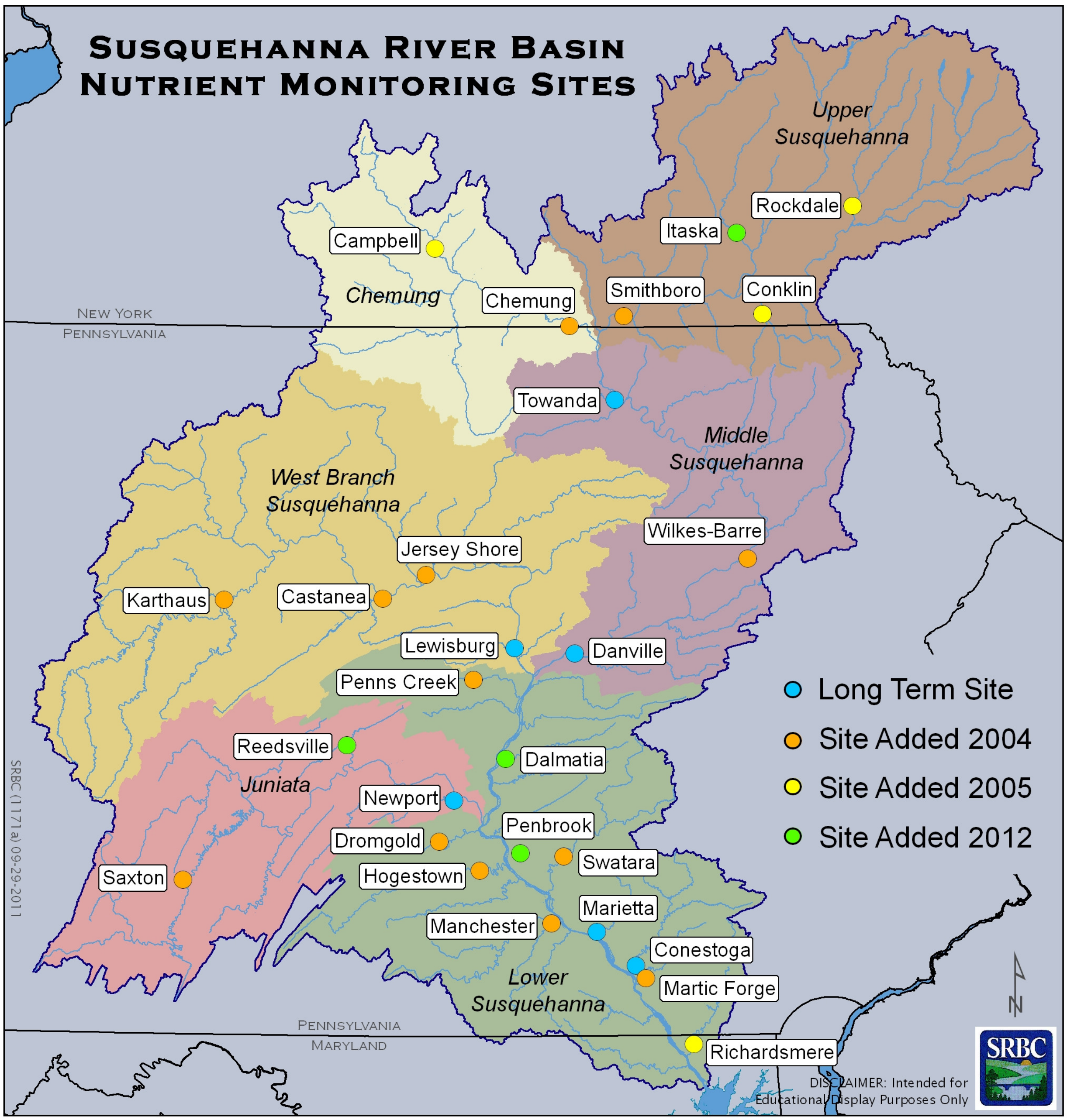

Figure 1. Locations of Sampling Sites Within the Susquehanna River Basin

Table 1. Data Collection Sites and Their Drainage Areas and 2000 Land Use Percentages

Site Location	USGS Site ID	Subbasin	Waterbody	Drainage Area (Sq. Mi.)	Water/ Wetland	Urban	Agricultural			Forest	Other
							Row Crops	Pasture Hay	Total		
Group A: Long-term Sites											
Towanda	01531500	Middle Susquehanna	Susquehanna	7,797	2	5	17	5	22	71	0
Danville	01540500	Middle Susquehanna	Susquehanna	11,220	2	6	16	5	21	70	1
Lewisburg	01553500	W Branch Susquehanna	W Branch Susquehanna	6,847	1	5	8	2	10	84	0
Newport	01567000	Juniata	Juniata	3,354	1	6	14	4	18	74	1
Marietta	01576000	Lower Susquehanna	Susquehanna	25,990	2	7	14	5	19	72	0
Conestoga	01576754	Lower Susquehanna	Conestoga	470	1	24	12	36	48	26	1
Group B: Enhanced Sites											
Rockdale	01502500	Upper Susquehanna	Unadilla	520	3	2	22	6	28	66	1
Conklin	01503000	Upper Susquehanna	Susquehanna	2,232	3	3	18	4	22	71	1
Smithboro	01515000	Upper Susquehanna	Susquehanna	4,631	3	5	17	5	22	70	0
Campbell	01529500	Chemung	Cohocton	470	3	4	13	6	19	74	0
Chemung	01531000	Chemung	Chemung	2,506	2	5	15	5	20	73	0
Wilkes-Barre	01536500	Middle Susquehanna	Susquehanna	9,960	2	6	16	5	21	71	0
Karthaus	01542500	W Branch Susquehanna	W Branch Susquehanna	1,462	1	6	11	1	12	80	1
Castanea	01548085	W Branch Susquehanna	Bald Eagle	420	1	8	11	3	14	76	1
Jersey Shore	01549760	W Branch Susquehanna	W Branch Susquehanna	5,225	1	4	6	1	7	87	1
Penns Creek	01555000	Lower Susquehanna	Penns	301	1	3	16	4	20	75	1
Saxton	01562000	Juniata	Raystown Branch Juniata	756	< 0.5	6	18	5	23	71	0
Dromgold	01568000	Lower Susquehanna	Shermans	200	1	4	15	6	21	74	0
Hogestown	01570000	Lower Susquehanna	Conodoguinet	470	1	11	38	6	44	43	1
Hershey	01573560	Lower Susquehanna	Swatara	483	2	14	18	10	28	56	0
Manchester	01574000	Lower Susquehanna	West Conewago	510	2	13	12	36	48	36	1
Martic Forge	01576787	Lower Susquehanna	Pequea	155	1	12	12	48	60	25	2
Richardsmere	01578475	Lower Susquehanna	Octoraro	177	1	10	16	47	63	24	2
Sites Beginning January 2012											
Itaska	01511500	Upper Susquehanna	Tioughnioga	730	2	4	22	5	27	66	1
Dalmatia	01555500	Lower Susquehanna	East Mahantango	162	1	6	20	6	26	66	1
Penbrook	01571000	Lower Susquehanna	Paxton	11	<0.5	50	9	11	20	29	1
Reedsville	01565000	Juniata	Kishacoquillas	164	<0.5	5	20	6	26	67	2
			Entire Susquehanna River Basin	27,510	2	7	14	7	21	69	1

Major urban areas in the Upper and Chemung Subbasins are located along river valleys, and they include Binghamton, Elmira, and Corning, N.Y. Urban areas in the Middle Susquehanna include Scranton and Wilkes-Barre, Pa. The major urban areas in the West Branch Susquehanna Subbasin are Williamsport, Lock Haven, and Clearfield, Pa. Lewistown and Altoona, Pa., are the major urban areas within the Juniata Subbasin. Major urban areas in the Lower Susquehanna Subbasin include York, Lancaster, Harrisburg, and Sunbury, Pa.

SAMPLE COLLECTION

2010 sampling efforts at the six long-term (Group A) sites included sampling during monthly base flow conditions, monthly flow independent conditions, and seasonal storm conditions. This resulted in two samples collected per month: one with a set date as close to the twelfth of each month which was independent of flow and one based on targeting monthly base flow conditions. The mid-monthly samples were intended to be flow independent with the intention that the data would help to quantify long-term trends. Additionally, due to the linkage of high flow and nutrient and sediment loads, it was necessary to target storm events for additional sampling in order to adequately quantify loads. Long-term site sampling goals included targeting one storm per season with a second storm collected during the spring season. Spring storms were planned to collect samples before and after agricultural crops had been planted.

All storm samples were collected during the rising and falling limbs of the hydrograph with goals of three samples on each side and one sample as close to the peak as possible. The enhanced sites (Group B) targeted a mid-monthly flow independent sample and two storm samples per season. Storm samples were planned to have one sample on the rising limb and one on the falling limb of the hydrograph with the goal that one of the two be as close to the peak as possible. Due to the quick nature of the hydrograph on several of the smaller streams, sometimes the two storm samples per season were taken from two different storms with the goal of having samples as close to the peak of each storm as possible.

The goal of actual sample collection was to collect a sample representative of the entire water column. Due to variations in stream width and depth and subsequent lack of natural mixture of the stream, it was necessary to composite several individual samples across the water column into one representative sample. The number of individual verticals at each site varied from three to ten dependent upon the stream width. Based on USGS depth integrated sampling methodology at each vertical location, the sampler was lowered at a consistent rate from the top of the water surface to the stream bottom and back to insure water from the entire vertical column was represented (Myers, 2006). Instream water quality readings were taken at each vertical to insure accurate dissolved oxygen and temperature values.

All samples were processed onsite and included whole water samples analyzed for nitrogen and phosphorus species, TOC, TSS, and SS. For Group B sites, SS samples were only collected during storm events. Additionally, filtered samples were processed onsite to analyze for dissolved nitrogen (DN) and DP species. Several sites included additional parameters pertinent to the natural gas industry.

SAMPLE ANALYSIS

Samples were either hand-delivered or shipped directly to the appropriate laboratory for analysis on the day following collection. When storm events occurred over the weekend, samples collected were analyzed on the following Monday. Samples collected in Pennsylvania. and at the Octoraro Creek site near Richardsmere, Md., were delivered to PADEP's Bureau of Laboratories in Harrisburg, Pa. Samples collected at New York sites were shipped to Columbia Analytical Services in Rochester, N.Y. Parameters for all samples at all sites included various nitrogen and phosphorus species, TOC, and TSS. Specific parameters, methodology, and detection limits are listed in Table 2.

Due to the high influence of stormflow on sediment concentrations, SS samples were collected during storm events at all sites with the goal of two samples for each event and one event per quarter. Of the two samples per storm, the more sediment laden sample was analyzed for both sediment concentration and sand/fine particle percentage. The additional sample was submitted for sediment concentration only. Sediment samples were shipped to the USGS sediment laboratory in Louisville, Kentucky, for analysis. Additional SS samples also were collected at all Group A sites as part of each sampling round. These samples were analyzed at the SRBC laboratory for sediment concentration alone.

Table 2. Water Quality Parameters, Laboratory Methods, and Detection Limits

Parameter	Storet	Laboratory	Methodology	Detection Limit (mg/l)	References
Total Ammonia (TNH_3)	610	PADEP	Colorimetry	0.020	USEPA 350.1
		CAS*	Colorimetry	0.010	USEPA 350.1R
Dissolved Ammonia (DNH_3)	608	PADEP	Block Digest, Colorimetry	0.020	USEPA 350.1
			Block Digest, Colorimetry	0.010	USEPA 350.1R
Total Nitrogen (TN)	600	PADEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Dissolved Nitrogen (DN)	602	PADEP	Persulfate Digestion	0.040	Standard Methods #4500-N_{org}-D
Total Organic Nitrogen (TON)	605	N/A	TN minus TNH_3 and TNOx	N/A	N/A
Dissolved Organic Nitrogen (DON)	607	N/A	DN minus DNH_3 and DNOx	N/A	N/A
Total Kjeldahl Nitrogen (TKN)	625	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Dissolved Kjeldahl Nitrogen (DKN)	623	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Total Nitrite plus Nitrate (TNOx)	630	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Nitrite plus Nitrate (DNOx)	631	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Orthophosphate (DOP)	671	PADEP	Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Dissolved Phosphorus (DP)	666	PADEP	Block Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Phosphorus (TP)	665	PADEP	Persulfate Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Organic Carbon (TOC)	680	PADEP	Combustion/Oxidation	0.50	SM 5310D
		CAS*	Chemical Oxidation	0.05	GEN 415.1/9060
Total Suspended Solids (TSS)	530	PADEP	Gravimetric	5.0	USGS I-3765
		CAS*	Residue, non-filterable	1.1	SM2540D
Suspended Sediment Fines	70331	USGS	**		
Suspended Sediment (SS)	80154	SRBC	**		
		USGS	**		

* Columbia Analytical Services, Rochester, N.Y. (New York sites only)
** TWRI Book 3, Chapter C2 and Book 5, Chapter C1, Laboratory Theory and Methods for Sediment Analysis (Guy and others, 1969)

PRECIPITATION AND DISCHARGE

Precipitation data were obtained from long-term monitoring stations operated by the U.S. Department of Commerce. The data are published as Climatological Data–Pennsylvania, and as Climatological Data–New York by the National Oceanic and Atmospheric Administration at the National Climatic Data Center in Asheville, North Carolina. Quarterly and annual data from these sources were compiled across the subbasins of the Susquehanna River Basin. Discharge values were obtained from the USGS gaging network system. All sites were collocated with USGS gages so that discharge amounts could be matched with each sample. Average daily discharge values for each site were used as input to the estimator model used to estimate nutrient and sediment loads and trends. Average monthly flow values were used to check for trends in discharge.

DATA ANALYSIS

Sample results were compiled into an existing database including all years of the program. These data were then listed on SRBC's web site as well as submitted to various partners for use with models and individual analyses. Specific analyses at SRBC include load and yield estimation, LTM comparisons, baseline comparisons, and trend estimation.

Loads and Yields

Loads and yields represent two methods for describing nutrient and SS amounts within a basin. Loads refer to the actual amount of the constituent being transported in the water column past a given point over a specific duration of time and are expressed in pounds. Yields compare the transported load with the acreage of the watershed and are expressed in lbs/acre. This allows for easy watershed comparisons. This project reports loads and yields for the constituents listed in Table 2 as computed by the Minimum Variance Unbiased Estimator (ESTIMATOR) described by Cohn and others (1989). This estimator relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. Daily loads of the constituents were then calculated from the daily mean water discharge records. The loads were reported along with the estimates of accuracy. Average concentrations were calculated by taking the total load and dividing by the total amount of flow during the time period and were reported in mg/L.

Load and trend analyses were not completed at Group B sites. Summary statistics have been calculated for these sites, as well as the long-term sites for comparison. Summary statistics are listed in Appendix B and include minimum, maximum, median, mean, and standard deviation values taken from the 2010 dataset.

Long-term Mean Ratios

Due to the relationship between stream discharge and nutrient and SS loading, it can be difficult to determine whether the changes observed were related to land use, nutrient availability, or simply fluctuations in water discharge. Although the relationship is not always linear at higher flows than lower flows, in general, increases in flows coincide with increases in constituent loads (Ott and others, 1991; Takita, 1996, 1998). In an attempt to determine annual changes from previous years, 2010 nutrient and SS loads, yields and concentrations were compared to LTMs. LTM load and discharge ratios were calculated for a variety of time frames including annual, seasonal, and monthly by dividing the 2010 value by the LTM for the same time frame reported as a percentage or ratio. It was thought that identifying sites where the percentage of LTM for a constituent, termed the load ratio, was different than the corresponding percentage of LTM for discharge, termed the water-discharge ratio or discharge ratio, would suggest areas where improvements or degradations may have occurred for that particular constituent. At odds with this conclusion is that individual high flow events tend to produce higher loads, especially for TP and SS, than would be predicted by a simple comparison with the LTM. Thus, the presence or absence of significant storm events during a time period tends to be the major contributing factor towards the resultant loads.

Baseline Comparisons

As a means to determine whether the annual fluctuations of nutrient and SS loads were due to water discharge, Ott and others (1991) used the relationship between annual loads and annual water discharge. This was accomplished by plotting the annual yields against the water-discharge ratio for a given year to calculate a baseline regression line. Data from the initial five-year study (1985-89) were used to provide a best-fit linear regression trend line to be used as the baseline relationship between annual yields and water discharge. It was hypothesized that as future yields and water-discharge ratios were plotted against the baseline, any significant deviation from the baseline would indicate that some change in the annual yield had occurred, and that further evaluations to determine the reason for the change were warranted.

Due to the size of the current dataset, the opportunity exists for there to be non-linear changes in the yield versus water discharge plot as more years are added. Therefore, this report included comparisons to baselines created from different time frames including the initial five-year period of data for each station, the first half of the entire dataset, the second half of the entire dataset, and the entire dataset. In order for each baseline comparison to be meaningful, the regression line needed to be best fit to the data. Although the tendency was for increasing loads to be associated with increasing flows, this relationship was not strictly linear, especially when dealing with TP and SS.

In several comparisons, an exponential regression line was used as it yielded a better fit to the data as determined by the associated R^2 value representing the strength of the correlation between the two parameters in the regression. The closer the R^2 is to a value of one, the better the regression line is for accurately using one variable (flow) to predict the other with an R^2 of one meaning that there is perfect correlation between the two variables. For example, R^2 values for TN tend to be close to one as the relationship between TN and flow is very consistent through various ranges of flows. R^2 values for TP and SS tend to vary more, especially towards higher flows. Thus, when regression graphs include high flow events, the resulting correlation tends to be less perfect indicated by a low R^2 value. This is an indication that single high flow events, and not necessarily a high flow year, are the highest contributors to loads in TP and SS and that these contributions do not necessarily follow a strictly linear increase. As has been evident in the last few years, the high loads that have occurred at Towanda and Danville can be linked directly to high flow events, specifically Tropical Storm Ernesto in 2006, Hurricane Ivan in 2004, and by the combination of a synoptic type storm events and Tropical Storm Nicole in 2010 (Maddox et al., 1979). Seasonal baselines also were calculated for the initial five years of data at each site.

Figure 2 shows the baseline regression line developed for TN at Marietta using the second half of the dataset where each hollow circle represents an individual year during the second half of the dataset. Each hollow circle was plotted using an individual year’s yield and the same year’s discharge ratio. The discharge ratio was calculated by dividing the year’s annual flow by the 12-year average flow for the baseline years used. A regression line was drawn through these data points and the equation of the trend line was used to calculate a baseline prediction for the 2010 yield given the 2010 discharge ratio. The baseline prediction for 2010 TN yield is shown as a square on the graph at 6.81 mg/L. The actual 2010 yield at the same discharge ratio, 6.11 mg/L, is shown as the solid circle. Since the actual 2010 yield was lower than the prediction made by the most recent 12 years of data, the comparison implies that improvements may have occurred.

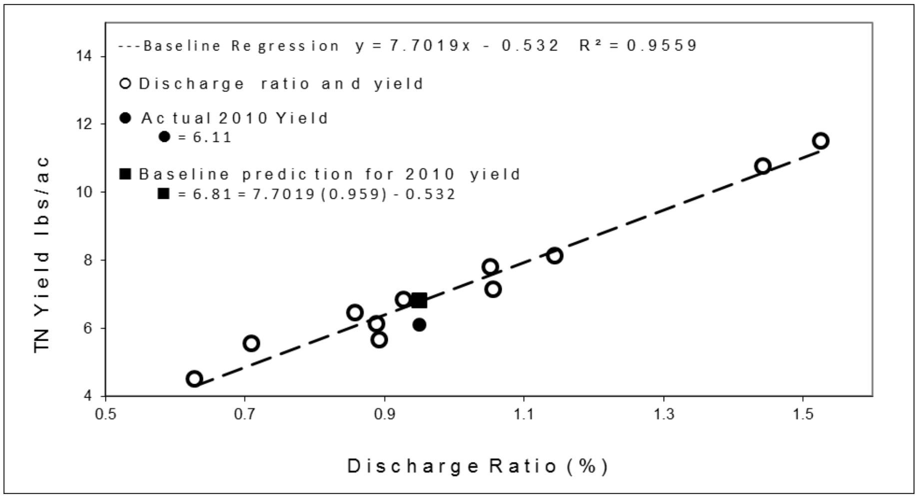

Figure 2. Second Half Baseline Regression Line, 2010 TN Yield Prediction, and Actual 2010 Yield for TN at Marietta

Figure 3 shows the baseline regression lines that were developed using the initial five years at Marietta, the first 12 years at Marietta, and the most recent 12 years at Marietta. Using multiple regression lines developed from different time periods within that dataset also can show whether changes occurred. The larger vertical oval in the graph shows the relevant comparison to be made; at a discharge ratio of 1.12, the initial five-year baseline predicts the 2010 yield to be 10.11 mg/L, while the actual 2010 yield was 6.11 mg/L (shown in the bottom of the oval). This suggests a more dramatic reduction than the comparison to the regression from the most recent 12 years which predicted the 2010 TN yield to be 6.81 mg/L shown within the smaller oval. Additional support for improvements can be seen when comparing the entire baseline regression lines to each other. As more recent years were added to the baseline, the entire regression line lowered. This implied that the more recent 12-year dataset included lower yield values as compared to the initial 12-year dataset. Thus, a regression line that predicts lower yields for the same water discharge ratio directly implies improved water quality between the two timeframes.

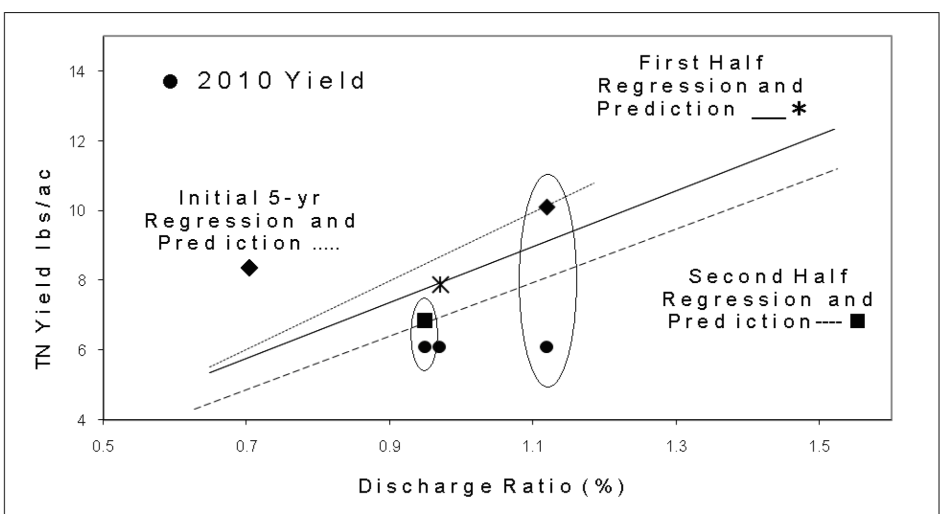

Figure 3. Initial, First Half, and Second Half Baseline Regression Lines, Yield Predictions, and Actual 2010 Yields for TN at Marietta

Flow-Adjusted Trends

Flow-Adjusted Concentration (FAC) trend analyses of water quality and flow data collected at Danville, Lewisburg, Newport, and Conestoga were completed for the period January 1985 through December 2010. Both Marietta and Towanda began later and their respective trend periods are 1987-2010 and 1989-2010. Trends were estimated based on the USGS water year, October 1 to September 30, using the USGS 7-parameter, log-linear regression model (ESTIMATOR) developed by Cohn and others (1989) and described in Langland and others (1999). ESTIMATOR relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. These tests were used to estimate the direction and magnitude of trends for discharge, SS, TOC, and several forms of nitrogen and phosphorus. Slope, p-value, and sigma (error) values are taken directly from ESTIMATOR output. These values are then used to calculate flow-adjusted trends using the following equations:

Trend =
$$100*(\exp(\text{Slope} *(\text{end yr} - \text{begin yr})) - 1)$$

Trend minimum =
$$100*(\exp((\text{Slope} - (1.96*\text{sigma})) *(\text{end yr} - \text{begin yr})) - 1)$$

Trend maximum =
$$100*(\exp((\text{Slope} + (1.96*\text{sigma})) *(\text{end yr} - \text{begin yr})) - 1)$$

The computer program S-Plus with the USGS ESTREND library addition was used to conduct Seasonal Kendall trend analysis on flows (Schertz and others, 1991). Trend results were reported for monthly mean discharge (FLOW) and individual parameter FACs. Trends in FLOW indicate any natural changes in hydrology. Changes in flow and the cumulative sources of flow (base flow and overland runoff) affect the observed concentrations and the estimated loads of nutrients and SS. The FAC is the concentration after the effects of flow are removed from the concentration time series. Trends in FAC indicate that changes have occurred in the processes that deliver constituents to the stream system. After the effects of flow are removed, this is the concentration that relates to the effects of nutrient-reduction activities and other actions taking place in the watershed. A description of the methodology is included in Langland and others (1999).

INDIVIDUAL SITES

Towanda

2010 annual discharge at Towanda was 94 percent of the LTM with above LTM values during the winter and fall months. Seasonal values ranged from 55 percent of LTM during summer to 145 percent of LTM during fall. All annual nutrient and sediment loads were below LTM except DOP. Annual load for DOP was 117 percent of the LTM and annual calculated concentration was 124 percent of the LTM. TN, TP, and SS load ratios were lower than the discharge ratios during all flows including the four high flow event months.

2010 yields for TN, TP, and SS were below all baseline comparisons. The actual 2010 TN yield was 3.61, while the prediction of the first half baseline was 6.17 and the second half baseline was 4.16. In addition to the 2010 value being lower than both predictions, this lower prediction of the second half baseline versus the first half baseline suggests a reduction between the two distinct time frames.

Initial five-year seasonal baseline comparisons support the idea that 2010 TN, TP, and SS yields have been reduced. The only exception existed during winter for TP and SS but could be due to the poor predictive ability of the regression shown by the low R^2 values. 2010 trend values continue to be downward for TOC, SS, and all nitrogen parameters except DNH_3. Phosphorus values were split between upward trends found for DOP and no trends found for TP and DP.

Figure 4 shows a plot of annual discharge ratios and annual mean concentrations of TN, TP, and SS for the entire dataset at Towanda 1989-2010. The TN plot shows a continual decrease throughout the dataset while the TP and

SS ratios fluctuate more with the discharge ratio. Two exceptions were found during 2003 and 2005. The annual discharge ratio for 2003 was the second highest of the dataset while the TP and SS concentration ratios remained relatively low. Additionally, during 2005 when the discharge ratio dipped down, the TP and SS ratios continued to be higher. Figure 5 shows the annual discharge ratio, the SS ratio, and the LTM ratio for the year's highest daily flow as compared to the annual peak value for other years. The highest daily flow ratio shows which years were influenced by individual high flow events versus years that had continual above average flows. All peaks in SS ratio correlate precisely with high daily flow ratio events. 2003 flows consisted of sustained above LTM flows but did not contain a substantial high flow event as did years 1993, 1996, and 2005. Thus, although the 2003 annual flow had the second highest discharge ratio due to sustained high flows, it did not have a single high event resulting in dramatic increases in SS concentrations. In contrast, 2005 had a lower annual discharge ratio that contained a single high flow event. This high flow event results in a peak in sediment concentrations for the year. The individual high energy event seemed to have more impact on the annual sediment load than did the sustained flow levels that were above the LTM.

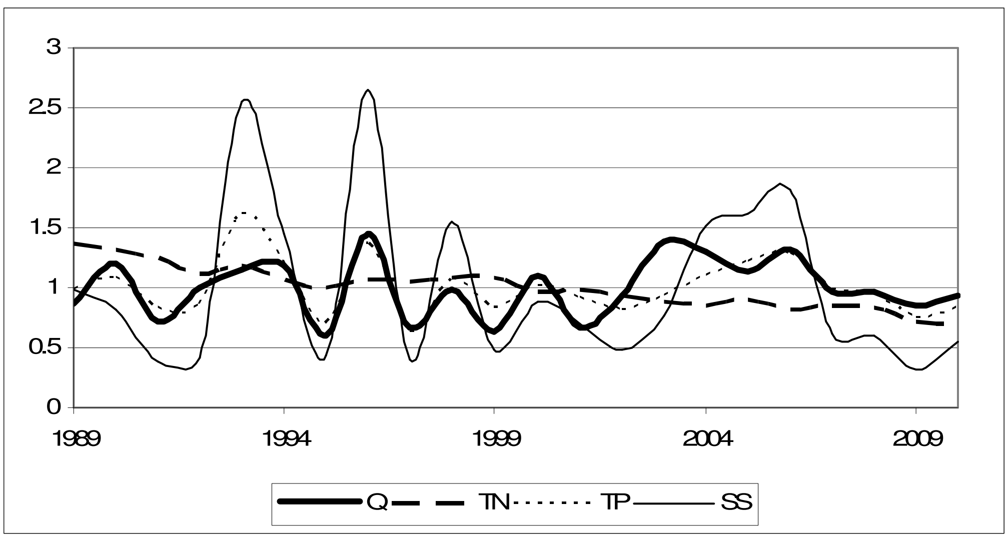

Figure 4. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

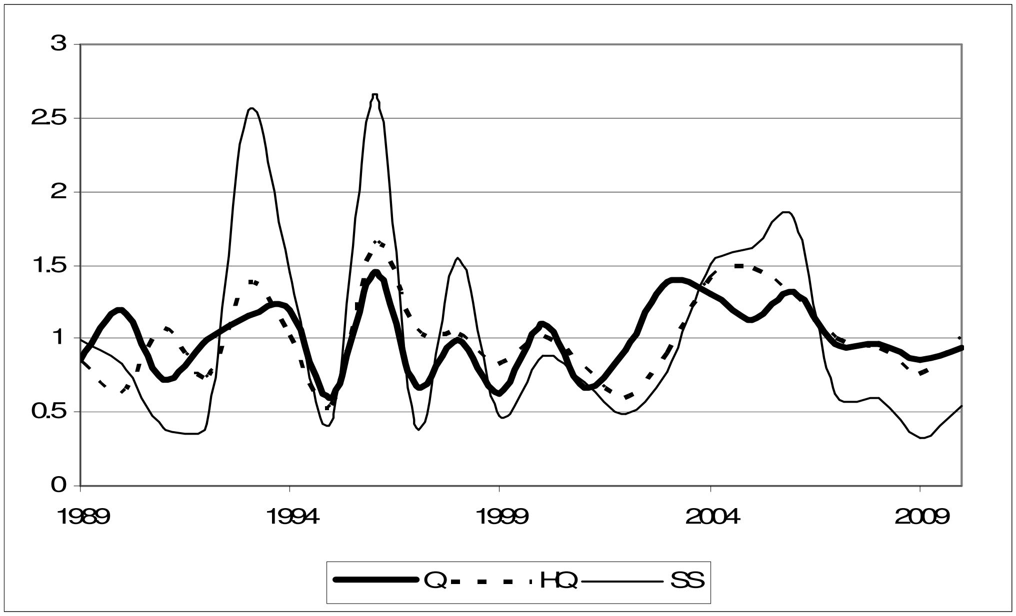

Figure 5. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Danville

2010 precipitation and flow distribution at Danville was comparable to Towanda. Highest precipitation amounts occurred during the fall months resulting in flow values of 142 percent of the LTM for the time period. 2010 annual flow was 94 percent of the LTM due to low flows during the spring and summer. Similarly to Towanda, Danville had below LTM flows leading to below LTM loads of TOC, SS, and all nutrients except DOP, which was 126 percent of the LTM for load and 134 percent of the LTM for average concentration. Monthly comparisons to LTMs suggest that TN has been reduced while, unlike Towanda, TP and SS were higher than LTM values during January and December and during October for SS only.

2010 yield comparisons for TN, TP, and SS showed similar changes as found at Towanda in that the initial five-year baselines had the highest predictions for 2010 followed by the first half baseline and the second half baseline, respectively. This change suggested that the rate of reduction had changed somewhere along the timeline. SS at Danville showed the biggest change when comparing the initial five-year baseline with the first half baseline. The initial baseline predicted the 2010 SS yield to be 907 lbs/acre/yr. With the addition of the next eight years of data into the baseline regression, the prediction was reduced to 356 lbs/acre/yr, implying that the following eight years had lower yield values, which lowered the regression line. This comparison showed similar results for both TN and TP at Danville.

2010 trends were downward for all nitrogen parameters except DHN_3 due to greater than 20 percent of the values being below the method detection limit (BMDL). Phosphorus trends were split, with downward trends for TP, no trends for DP, and no trends for DOP due to BMDL. TOC and SS both had downward trends including a 42-60 percent reduction in flow-adjusted sediment concentrations over the entire time period.

Annual mean concentrations also showed a pattern of continual TN decreases and varying TP and SS concentrations based more on flow regime. Comparison of the 2003 values in Figures 6 and 7 again showed that individual peak flow events were more influential than high annual flow values.

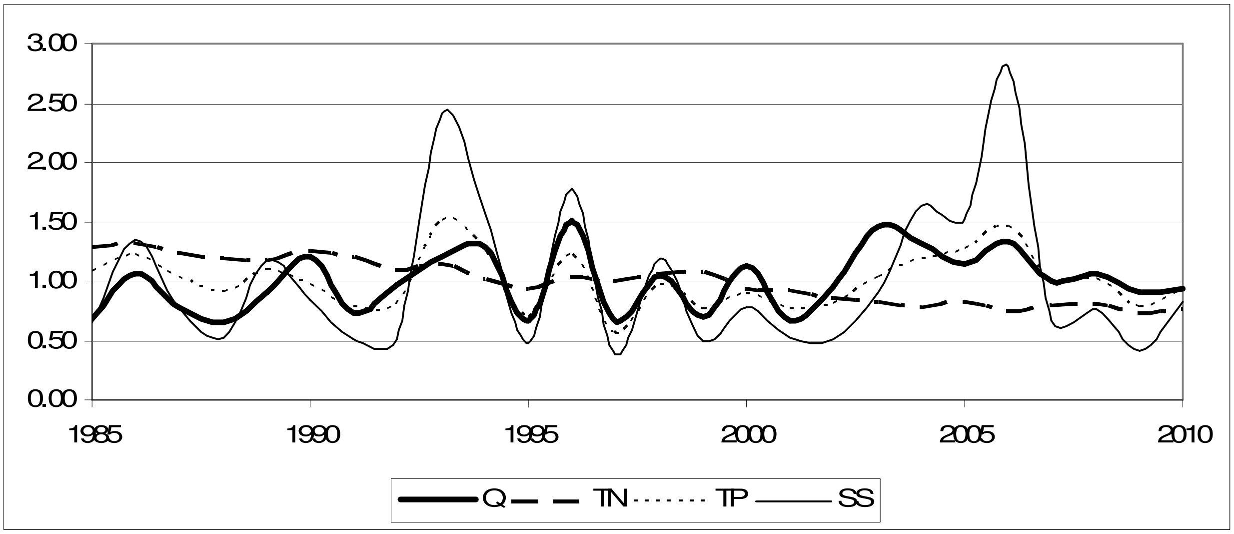

***Figure 6.	Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio***

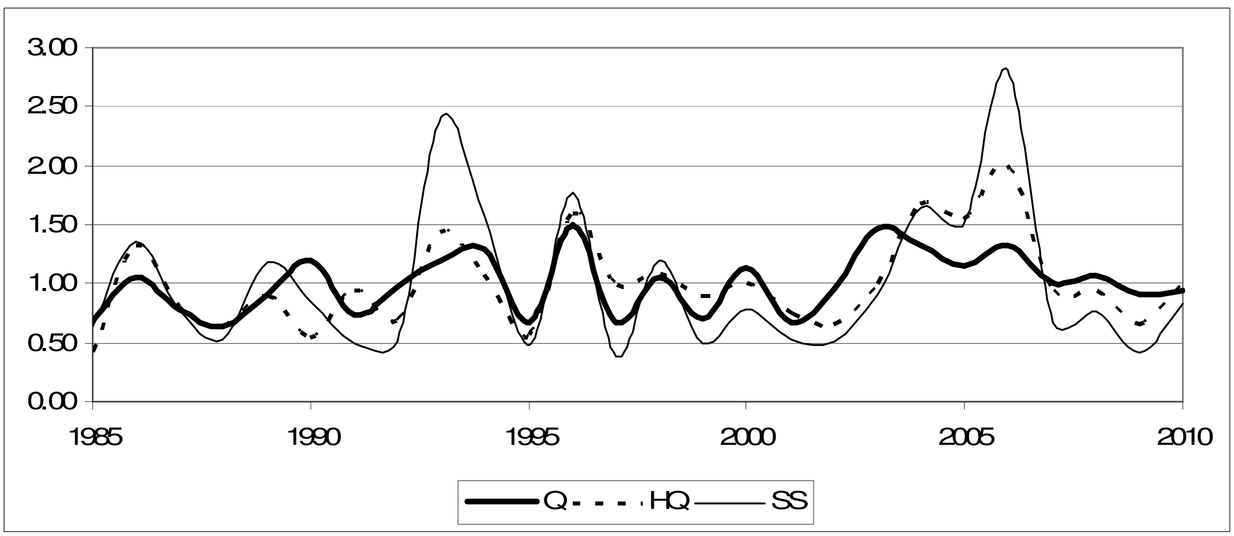

***Figure 7.	Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio***

Marietta

Although 2010 precipitation values for Marietta were similar to Towanda and Danville, there were differences in seasonal discharge. Differences in discharge during the fall months were due to storm event location. Specifically, October's event brought less rainfall and subsequent lower flows to Newport and Lewisburg while having very high flows at Conestoga. In contrast, December's storm was the top discharge event at Lewisburg and the second highest event at Newport. Annual load LTM ratios at Marietta were below the discharge ratio for all parameters except SS. Closer analysis of monthly loads showed that January and February accounted for nearly half of the annual sediment load, while December accounted for an additional third, making it the highest sediment load month of the year at Marietta. Although the October load LTM ratio for SS was above the discharge ratio, the total load was less than 8 percent of the annual load.

2010 TN yields were below baseline predictions for initial, first half, and second half baselines, suggesting continued reductions in load throughout the entire dataset, with biggest improvements apparent when compared with the initial five-year baseline. Although 2010 TP yields were below all annual baseline comparisons, seasonal comparisons with the five-year baselines were above prediction for winter. The 2010 annual SS yield value was above all baseline predictions. Looking at the initial five-year seasonal baselines showed that both winter and fall were the reason for annual SS to be higher than predicted, with the winter prediction being 91 lbs/acre and the actual 2010 yield being 205 lbs/acre. The baseline prediction for fall was 150 lbs/acre and the actual yield was 184 lbs/acre. All parameters except DOP and DHN had downward trends for the time period from 1987 to 2010.

The annual concentration ratios in Figures 8 and 9 again show the continual decrease of TN ratios through the duration of the dataset alongside less consistent changes for TP and SS. Figure 9 shows the same 2003 relationship between high annual flow with no significant high flow event and subsequent low SS concentrations. 1996 was a year that had both a very high peak event in January followed by high flows throughout the rest of the year. This high volume of water overall lowered the average annual calculated concentration below the discharge ratio for the peak flow event, which did not happen for most years. Comparisons between the two highest peak flow events for the dataset can be made between 1996 and 2004. 1996 annual discharge was 63,558 cfs and peak flow event was 601,000 cfs compared to 56,023 and 557,000 for 2004. Although both the higher annual flow and the peak event flow event occurred during 1996, the resultant SS loads were higher during 2004 at 19.79 billion pounds versus 16.5 billions pounds for 1996. This difference may be due to the timing of the peak flow events: the 1996 peak flow event occurred during January, while the 2004 peak flow event occurred during September. Another factor was the 2004 SS input from Newport which was the highest annual SS load of the entire time period there.

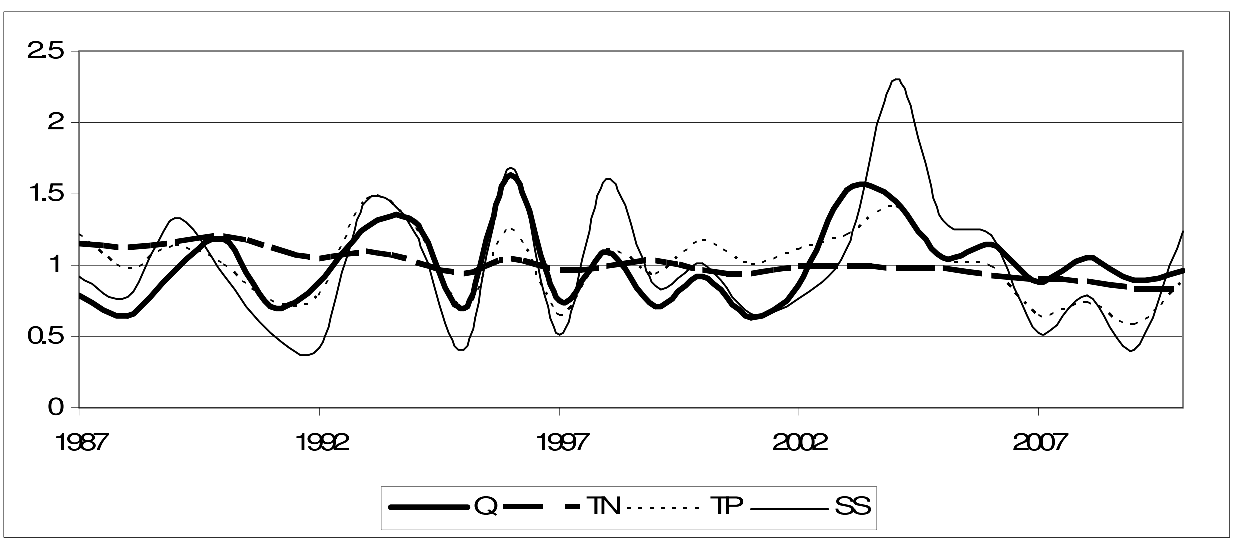

Figure 8. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

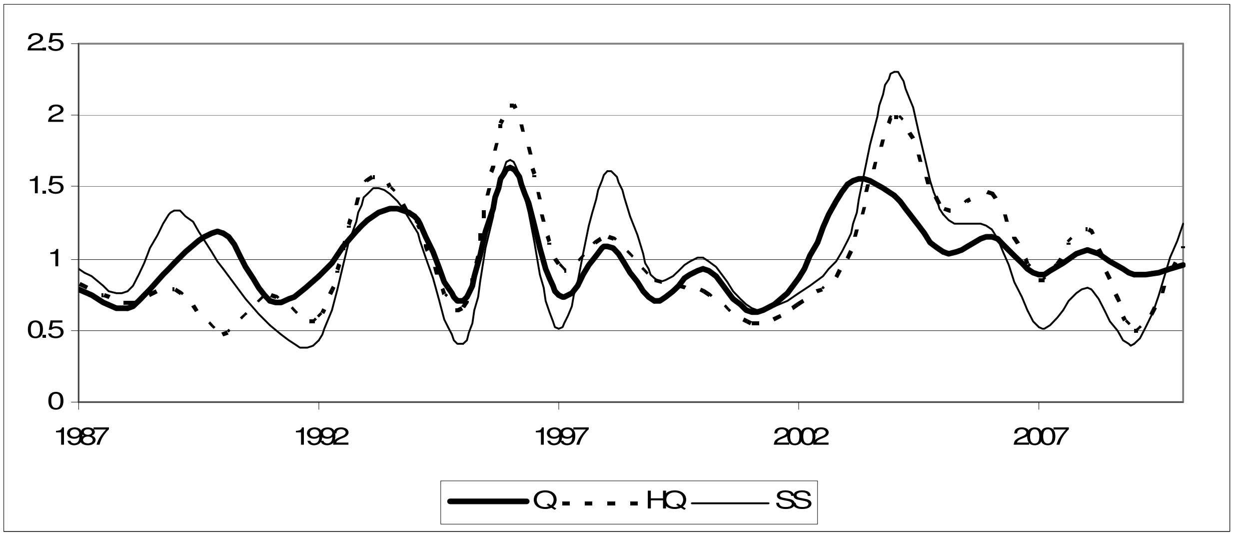

Figure 9. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Lewisburg

2010 precipitation at Lewisburg was less than an inch above normal with 3 inches above the LTM during the fall months. This was due to a large storm event during December. Discharge ratios ranged from 35 percent of the LTM during summer to 130 percent of the LTM during fall with an annual average that was 92 percent of LTM. Specifically, December had the highest discharge ratio at 172 percent of the LTM. Monthly load ratios were lower than the discharge ratio for TN, TP, and SS during January, March, and October. The December TN load ratio was lower than the discharge ratio while TP was slightly above and SS was more than double and accounted for nearly 50 percent of the annual sediment load.

Baseline comparisons showed the same tendencies with the initial baseline showing the biggest improvements with a TN yield prediction that was 167 percent of the actual 2010 yield of 3.63 lbs/acre. The second half baseline predicted the 2010 discharge ratio to have a yield that was 120 percent of the actual value. All four baseline comparisons predicted lower SS yields than were actually found for 2010 suggesting worsened conditions. Seasonal baselines for SS show that the primary cause was the fall season and specifically, the high flow event that occurred during December that had a yield that was 227 percent of the predicted value.

Trends at Lewisburg were downward for most parameters, with TNH, DNH, DP, and DOP having no trends due to BMDL. TOC showed no trends while TON and DON showed the highest reductions over the time period, ranging from 48-62 percent for DON and 56-69 percent for TON.

Average annual concentrations showed distinct variations between 1993, 1996, and 2004. Both 1993 and 1996 had high annual flows and an individual high flow event that both resulted in substantially high SS annual concentrations. 2004 had both high annual flow and the highest peak event for the entire time frame, yet had much lower SS annual concentrations. This could be due to timing of peak flow events which occurred during April for 1993, January for 1996, and September for 2004.

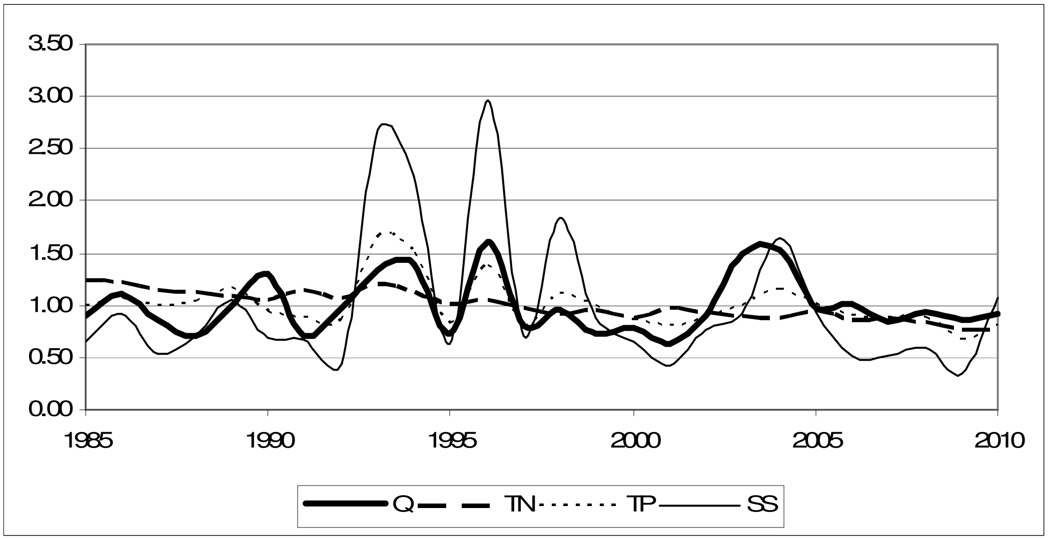

Figure 10. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

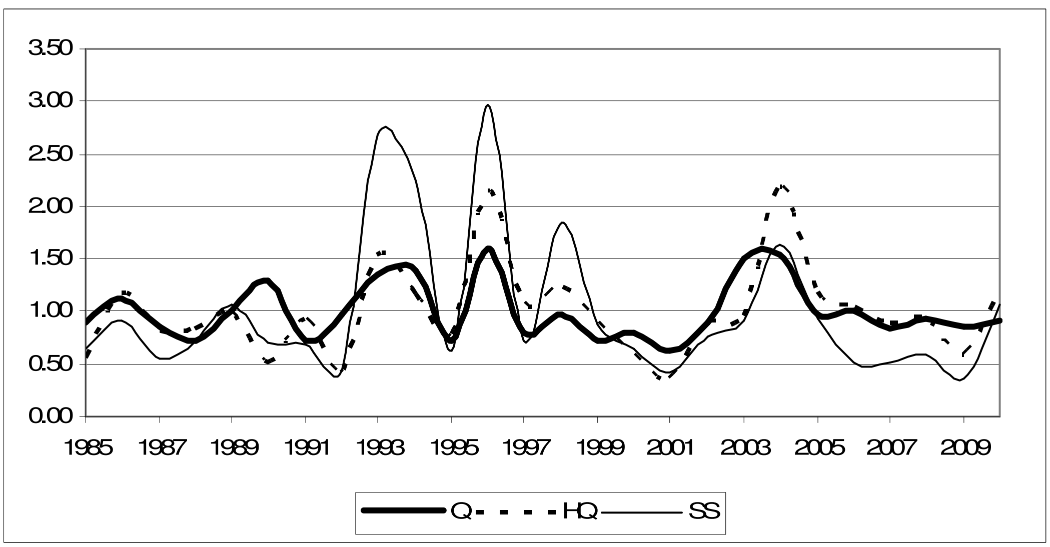

Figure 11. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Newport

Precipitation and discharge at Newport were very similar to Lewisburg during 2010. Above LTM precipitation occurred during all seasons except spring, while above LTM flow occurred during winter and fall. Similar to Lewisburg, monthly TN load ratios were below monthly discharge ratios for all months. Unlike Lewisburg, both TP and SS were above the discharge ratios during March and December at Newport, accounting for 54 percent and 68 percent of the 2010 annual TP and SS load, respectively. TN and TP yields were below all baseline predictions while SS yields were only lower than the initial five-year baseline.

Comparison of baseline predictions to each other for TN and TP show improvements between the initial five-year baseline and the first half baseline but showed relatively no change between the predictions of first half, second half, and full dataset baseline predictions. Since adding additional years to the baseline regression does not change the 2010 prediction, it can be inferred that improvements that may have occurred early in the data period have not continued through the rest of the time period. Seasonal baseline predictions showed improvement for TN, TP, and SS for all seasons except SS during fall due to the high flow event in December.

Significant trends at Newport included downward trends for all TN species except TNH_3 and DHN_3, which had no trends due to BMDL. TP and DP both showed downward trends while DOP had increasing trends. TOC and SS had downward trends through 2010.

The TN downward trend was between 10 and 19 percent over the time frame. Figure 12 shows a similar small reduction in TN annual concentration from 1985 to 2010. Figure 13 shows a similar pattern for peak high flows in 1996 and 2004 as compared to Marietta in Figure 9 and in contrast to Lewisburg in Figure 11. Although annual flow and peak flows were comparable between the two years, there was a dramatic difference in SS concentration with 2004 being much higher. The 2004 increase in SS load was a larger contributor to the sediment levels at Marietta during 2004 as compared to 1996.

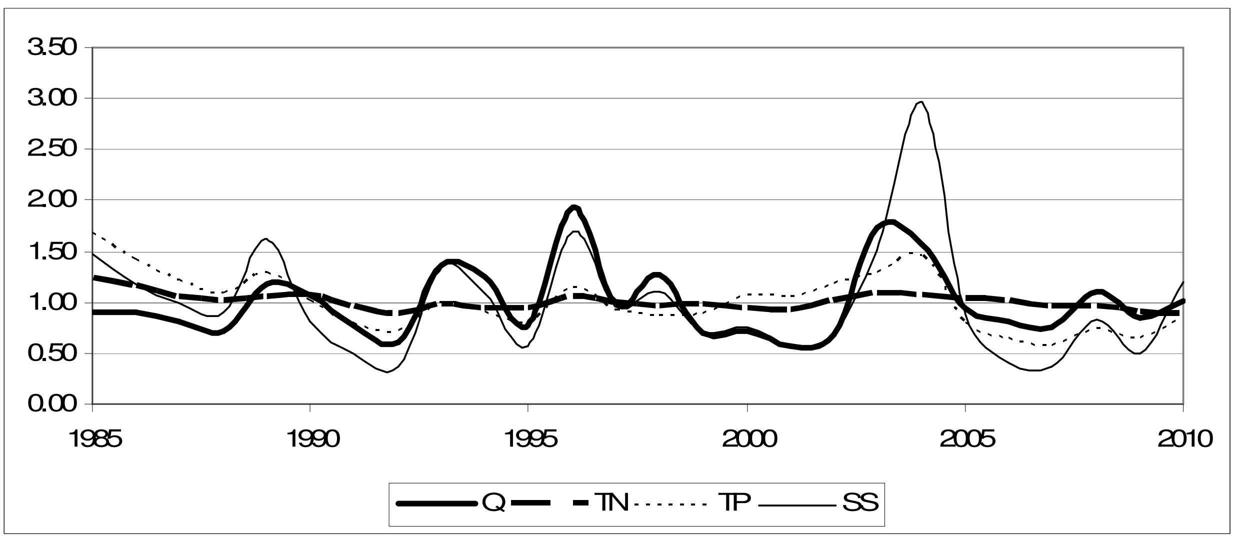

Figure 12. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

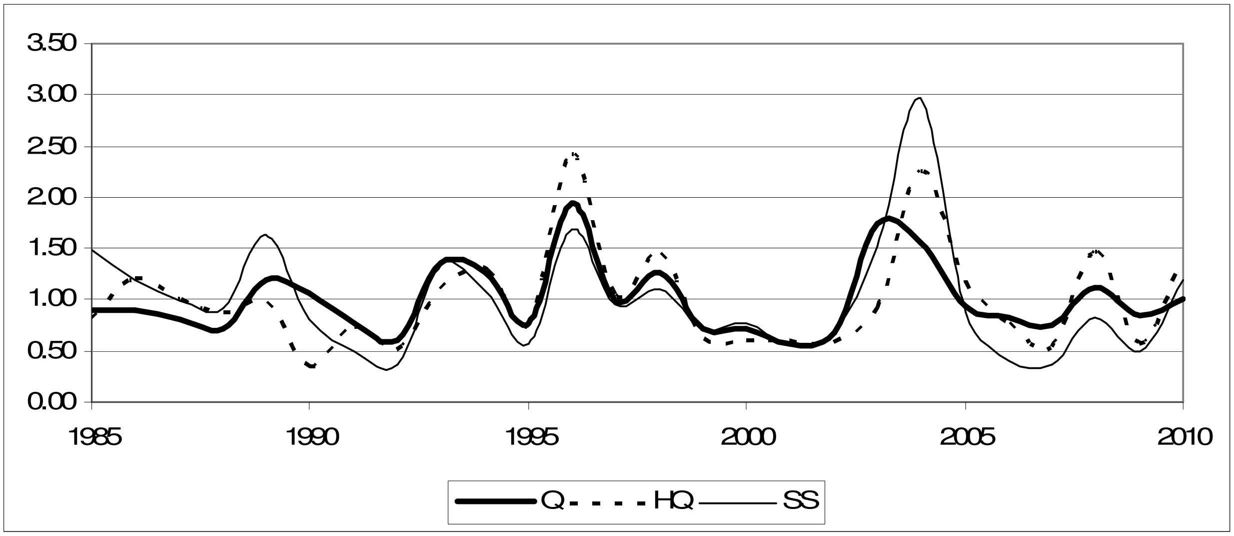

Figure 13. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

Conestoga

Annual flow at Conestoga was 96 percent of the LTM with seasonal flow ranging from 73 percent of the LTM during summer to 108 percent of the LTM during winter. Two significant events occurred during the year, the first during March, which was 127 percent of the LTM and the second during October, which was 195 percent of the LTM. TN, TP, and SS were below their respective LTMs during March. Only TN was below LTM during October while TP was 329 percent of the LTM and SS was 705 percent of the LTM and accounted for 39 and 59 percent of the TP and SS annual load, respectively. Although the majority of the flow and transported TP and SS occurred during October, the storm actually began on September 30, which led to load ratios for TP and SS to be above the 70 percent discharge ratio for the month.

All baseline comparisons showed improvements for TN, TP, and SS except for the second half of the baseline for SS. The biggest reason for this was the fall SS yields due to the October flow event. The initial baseline predicted the 2010 yield to be 189 lbs/acre with the actual value being 629. Reductions in other seasons, like spring with the actual 2010 value being 73 compared with the prediction of 321, offset the fall values.

All trends were downward at Conestoga except TNOx and DNOx, which had no trends. The most significant reductions occurred for TNH_3 and DNH_3, with between 73-80 and 74-81 percent, respectively. There was a distinct difference between TON and DON reductions with the former being 50-62 percent and the latter 6-27 percent. Reductions of around 50 percent were also found for SS, TOC, TP, and DP.

Annual mean concentrations at Conestoga are shown in Figures 14 and 15. TN shows a discernable reduction in average concentration through the time period. Although both TP and SS trends show more ups and downs, they also seem to show reducing concentrations through the time period with very low values during several recent years from 2007 through 2009. There were many distinctions from other sites when looking at annual peak flow and annual flow versus SS concentrations. 1999 and 2000 had below LTM annual flows and at least one significant event, which led to the highest annual concentrations for the entire time period. This suggests that the single events were the highest contributor. Actual annual load values for the dataset were highest during 1996 then 1993 and 2000.

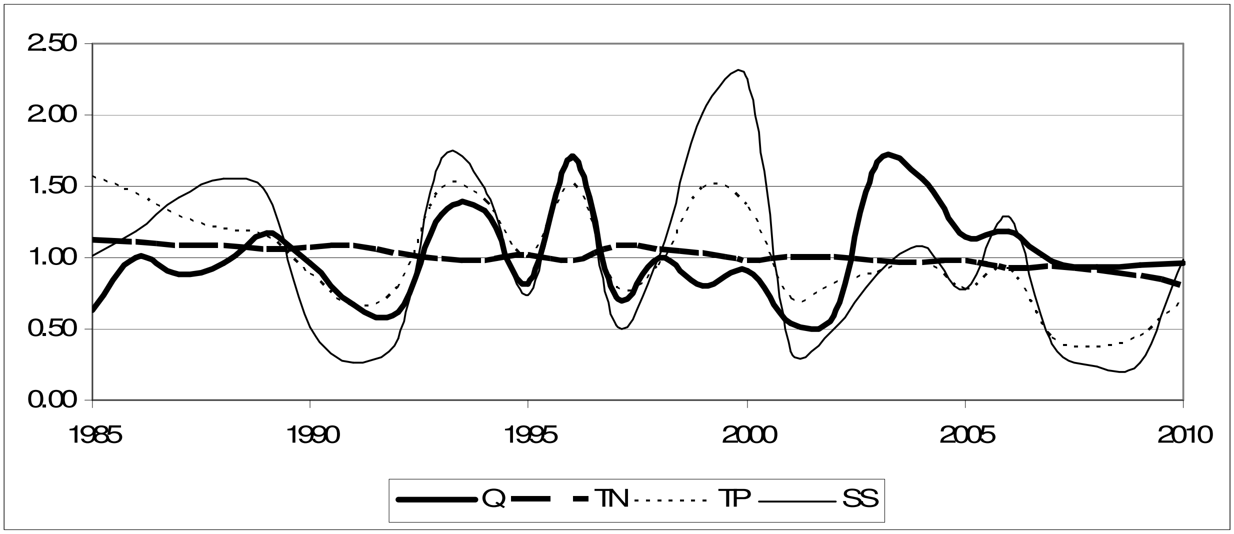

Figure 14. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

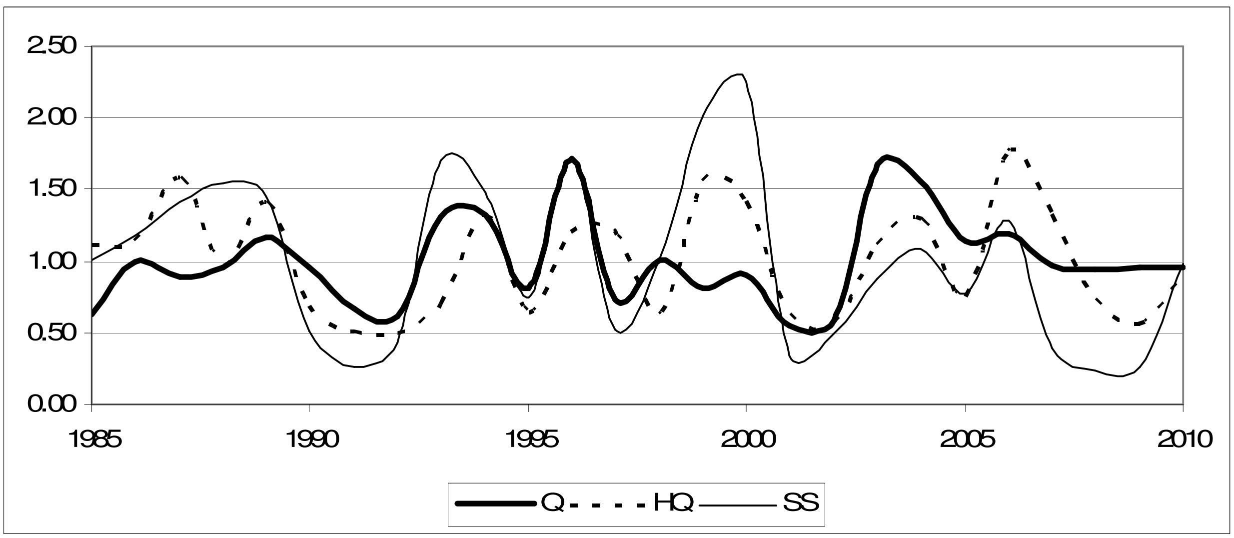

Figure 15. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

2010 KEY FINDINGS

2010 precipitation was dominated by four major rainfall events during the winter months of January and March and the fall months of October and December. The March event was a nor'easter and the other three were Maddox Synoptic type events (Maddox et al., 1979). Synoptic type events are most common during the spring and early summer and again in fall and early winter. These events involve unique interactions resulting in fronts that are usually oriented southwest to northeast and involve extreme amounts of precipitation. A more specific description of the events is given in Maddox et al. (1979).

All four events resulted in substantial rainfall and subsequent rises in stream discharge at all mainstem Susquehanna sites. The fall storms had more isolated effects on the three tributary sites where the October event resulted in comparatively small rises in flow at Newport and Lewisburg while it resulted in very high rises at the Conestoga site. The other three major events had minimal impact at Conestoga. Table 3 shows flow and nutrient amounts for the four high flow months including percentage of the annual flow and precipitation, the percent of LTM for flow, and the TN, TP, and SS percent of annual loads. For example, total precipitation for January, March, October, and December was 39 percent of the total annual precipitation. Total discharge for the same months was 61 percent of the total annual flow and 136 percent of the LTM for the same months during previous years. Regarding nutrients, these months accounted for 62-64 percent of the annual TN load, 69-77 percent of the annual TP load, and 83-91 percent of the annual SS loads.

Table 3. January, March, October, and December Total Precipitation, Flow, and Nutrient Loads as Percentage of Annual Totals and the Percent of LTM for Flow

Site	Precip	Flow	Flow LTM	TN	TP	SS
Towanda	39	61	136	63	71	88
Danville	40	59	133	62	69	83
Lewisburg	39	62	135	64	77	88
Marietta	40	60	138	63	73	91
Newport	38	60	146	64	74	88
Conestoga	38	49	118	50	60	75

Baseline comparisons have shown several changes in water quality through the data period at each site. All comparisons of 2010 yields to the initial baseline have shown dramatic improvements. Additionally, comparisons of first and second half baselines have consistently shown that water quality has improved between these two periods. Comparing both periods to the initial five-year dataset at each site shows that there were larger improvements early on in the data period and that the rate of improvements seems to have reduced somewhere in the middle of the period.

TN load ratios were consistently lower than the corresponding discharge ratios at all sites while TP and SS load ratios varied depending on whether the discharge ratio was above or below the LTM. Typically, for discharge ratios above the LTM, TP and SS load ratios were above the actual discharge ratio, whereas the load ratios tended to be below the discharge ratio when the discharge ratio was below the LTM. Thus, below LTM flow periods tend to show greatest reductions as compared to flow above the LTM. The driving factor behind this observation seemed to be the presence or absence of individual peak flow events. Implications could be that there was more bank/streambed scour or that there was more erosion from increased overland flow and less infiltration. High levels of impervious surfaces as well as subsurface drainage on farm lands potentially lead to quicker and higher hydrograph rises resulting in higher energy for streambank erosion and streambed scour. It may be that the effects of management actions are apparent during time periods where individual high flow events are absent but that they are being erased when they are present. The major implication being that management of nutrient and sediment loads is directly related to our ability to manage the impact of high flow events. With the addition of impervious surfaces and storm runoff controls that funnel water quickly into the streams and rivers, it may be that the characteristics of the hydrograph have been altered resulting in quicker, higher peaks that have higher energy and ability to scour streambanks and beds.

Flow-adjusted trends were meant to remove the effects of flow on concentrations leading to a trend that is directly related to management action as opposed to variations in flow such as the four peak events that occurred in 2010. Consistent, basinwide trend results at all sites included downward trends for TN, DN, TON, DON, and SS. Other common trends were TP being downward at all sites except Towanda, and TOC being downward at all sites except Lewisburg. Unique findings included DP having no trend at both Towanda and Danville while DOP had upward trends at Towanda and Newport. The two sites with the most downward trends were Marietta with all downward except DNH_3 and DOP, which had no trends, and Conestoga, which had downward trends for all except TNOx and DNOx. Conestoga also was the only site to have downward trends for all phosphorus species.

2010 presented a year with significant rainfall events that were isolated to the winter and fall months and with offsetting lower flow seasons in the spring and summer. This led to the majority of loads being transported during these high flow seasons that contained the high flow storms. 2011 has presented a different flow year to date including multiple extreme events that occurred during the entire calendar year. This included a very wet winter and spring followed by sustained flow levels above the historic median values at Marietta for August through November, and drastic flooding due to Hurricane Irene and Tropical Storm Lee. Extensive monitoring was conducted during both events to capture the amounts of nutrients and SS transported through these historical events. Analysis of the peak event data will provide a unique glimpse into water quality at these long-term sites and the effects of extreme events that seem to be the major player in nutrient and SS transport.

REFERENCES

Cohn, T.A., L.L DeLong, E.J. Gilroy, R.M. Hirsch, and D.E Wells. 1989. Estimating Constituent Loads. *Water Resources Research*, 25(5), pp. 937-942.

Guy, H.P. and V.W. Norman. 1969. Field Methods for Measurement of Fluvial Sediment. U.S. Geological Survey Techniques of Water Resources Investigation, Book 3, Chapter C2 and Book 5, Chapter C1.

Langland, M.J. 2000. "Delivery of Sediment and Nutrients in the Susquehanna, History, and Patterns." The Impact of Susquehanna Sediments on the Chesapeake Bay, Chesapeake Bay Program Scientific and Technical Advisory Committee Workshop Report.

Langland, M.J., J.D. Bloomquist, L.A. Sprague, and R.E. Edwards. 1999. Trends and Status of Flow, Nutrients, Sediments for Nontidal Sites in the Chesapeake Bay Watershed, 1985-98. U.S. Geological Survey (Open-File Report), 64 pp. (draft).

Maddox, R.A., C.F. Chappell, and L.R. Hoxit. 1979. Synoptic and Meso-α Scale Aspects of Flash Flood Events. Bull. Amer. Meteor. Soc., 60, pp. 115–123.

Myers, M.D. 2006. National Field Manual for the Collection of Water-Quality Data. U.S Geological Survey Techniques of Water Resources Investigation, Book 9, Chapter A4.

Ott, A.N., L.A. Reed, C.S. Takita, R.E. Edwards, and S.W. Bollinger. 1991. Loads and Yields of Nutrient and Suspended Sediment Transported in the Susquehanna River Basin, 1985-89. Publication No. 136. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

Schertz, T.L., R.B. Alexander, and D.J. Ohe. 1991. The computer program EStimate TREND (ESTREND), a system for the detection of trends in water-quality data: U.S. Geological Survey Water-Resources Investigations Report 91-4040, 63 pp.

Susquehanna River Basin Study Coordination Committee. 1970. Susquehanna River Basin Study, 156 pp.

Takita, C.S. 1998. Nutrient and Suspended Sediment Transported in the Susquehanna River Basin, 1994-96, and Loading Trends, Calendar Years 1985-96. Publication No. 194. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

——. 1996. Nutrient and Suspended Sediment Transported in the Susquehanna River Basin, 1992-93. Publication No. 174. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

Takita, C.S. and R.E. Edwards. 1993. Nutrient and Suspended Sediment Transported in the Susquehanna River Basin, 1990-91. Publication No. 150. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

U.S. Environmental Protection Agency (USEPA). 1982. Chesapeake Bay Program Technical Studies: A Synthesis, 634 pp.

APPENDIX A

Individual Site Data

INDIVIDUAL SITES: TOWANDA

Table A1. 2010 Annual and Seasonal Precipitation and Discharge at Towanda

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	2010 Discharge	Discharge LTM	% LTM
January-March (Winter)	8.58	7.59	0.99	17,170	16,515	104%
April-June (Spring)	10.06	10.59	-0.53	8,975	15,178	59%
July-September (Summer)	10.15	11.18	-1.03	2,469	4,518	55%
October-December (Fall)	12.87	9.28	3.59	15,719	10,811	145%
Annual Total	41.66	38.64	3.02	10,987	11,732	94%

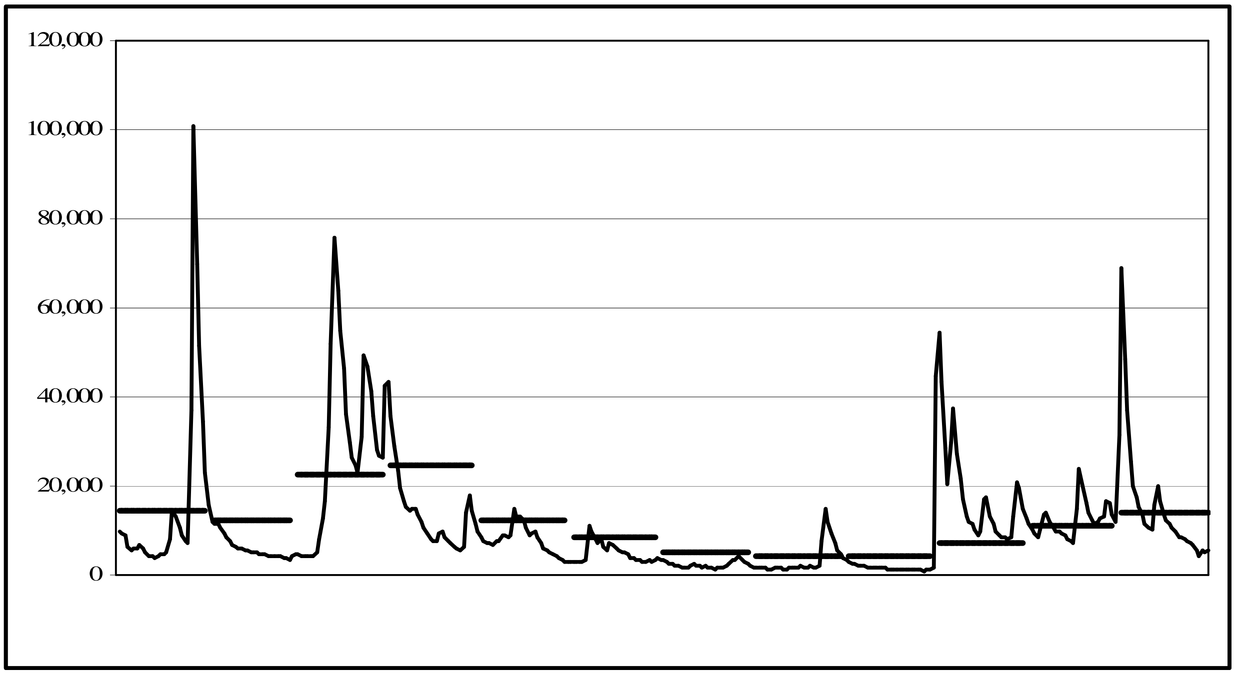

Figure A1. 2010 Daily Average Flow and Monthly LTM at Towanda

Table A2. 2010 Annual Loads, Yields, and Concentrations at Towanda

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/acre/yr	LTM Yield lb/acre/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	18,016	67	3	3.61	5.43	0.83	71
TP	1,710	75	9	0.34	0.46	0.08	80
SS	1,306,392	46	15	262	571	60	49
TNH_3	645	49	12	0.13	0.27	0.03	52
TNO_{23}	10,020	62	4	2.01	3.23	0.46	66
TON	7,289	74	7	1.46	1.98	0.34	79
DN	16,488	70	4	3.30	4.75	0.76	74
DNH_3	568	54	11	0.11	0.21	0.03	58
DNO_{23}	10,050	63	4	2.01	3.20	0.46	67
DON	5,551	80	8	1.11	1.40	0.26	85
DP	661	83	10	0.132	0.160	0.031	89
DOP	520	117	12	0.104	0.089	0.024	124
TOC	70,189	86	3	14.07	16.30	3.25	92

Table A3. 2010 Seasonal Loads and Yields at Towanda

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	7,857	1.57	3,519	0.71	780	0.16	5,859	1.17
TNOx	4,575	0.917	1,924	0.386	319	0.064	3,203	0.642
TON	2,834	0.568	1,410	0.283	528	0.106	2,517	0.504
TNH_3	296	0.059	108	0.022	28	0.006	212	0.043
DN	7,114	1.43	3,228	0.65	646	0.13	5,499	1.10
DNOx	4,581	0.918	1,933	0.387	313	0.063	3,222	0.646
DON	2,067	0.414	1,138	0.228	375	0.075	1,971	0.395
DNH_3	268	0.054	105	0.021	25	0.005	171	0.034
TP	759	0.152	272	0.054	83	0.017	596	0.120
DP	251	0.050	136	0.027	46	0.009	228	0.046
DOP	200	0.040	105	0.021	34	0.007	180	0.036
TOC	24,498	4.91	12,621	2.53	4,531	0.91	28,538	5.72
SS	724,031	145	102,169	20	16,255	3	463,937	93

Table A4. 2010 Monthly Flow, Loads, and Yields at Towanda

Month	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	16,240	114%	2,608	0.52	84%	268	0.054	107%	313,780	62.9	81%
February	6,202	50%	861	0.17	34%	37	0.007	27%	5,761	1.2	6%
March	28,007	122%	4,388	0.88	92%	454	0.091	119%	404,489	81.1	91%
April	14,048	57%	1,951	0.39	39%	148	0.030	33%	71,112	14.3	10%
May	7,926	64%	1,012	0.20	44%	75	0.015	45%	20,131	4.0	10%
June	4,985	58%	557	0.11	40%	48	0.010	32%	10,926	2.2	4%
July	2,369	47%	255	0.05	33%	26	0.005	32%	3,557	0.7	4%
August	3,315	78%	349	0.07	55%	39	0.008	56%	10,736	2.2	17%
September	1,698	40%	176	0.04	28%	18	0.004	21%	1,963	0.4	1%
October	18,819	259%	2,187	0.44	175%	294	0.059	225%	269,657	54.0	218%
November	12,326	110%	1,496	0.30	73%	108	0.022	60%	37,082	7.4	23%
December	15,903	114%	2,175	0.44	79%	194	0.039	94%	157,198	31.5	92%
Annual#	10,987		18,016	3.61		1,710	0.343		1,306,392	261.8	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A5. 2010 Annual Comparison to Baselines at Towanda

Parameter	2010	Period	Y'	Q ratio	R^2
TN	3.61	89-93	6.48	0.95	0.87*
		89-99	5.90	0.99	0.89*
		00-10	4.10	0.89	0.85*
		89-10	4.91	0.94	0.65*
TP	0.343	89-93	0.42	0.95	0.82*
		89-99	0.42	0.99	0.92*
		00-10	0.35	0.89	0.85*
		89-10	0.38	0.94	0.88*
SS	261.8	89-93	360	0.95	0.54*
		89-99	448	0.99	0.81*
		00-10	273	0.89	0.68*
		89-10	338	0.94	0.74*

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used instead of a linear regression as it yielded a higher R^2
# indicates a R^2 that is low and thus is less accurate at predicting

Table A6. 2010 Annual and Seasonal Comparison to Initial Five-Year Baselines at Towanda

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.20	0.99*	2.59	1.57	0.69*	0.148	0.152	0.20*#	107	145
Spring	0.50	0.97	1.20	0.71	1.00*	0.063	0.054	1.00*	35	21
Summer	0.79	0.99	0.28	0.16	0.99	0.019	0.017	0.94*	2	3
Fall	1.39	0.98	2.28	1.17	0.97*	0.171	0.120	0.92*	124	93
Annual	0.95	0.87*	6.48	3.61	0.82*	0.420	0.343	0.54*	360	262

* indicates where an exponential regression was used instead of a linear regression as it yielded a higher R^2
# indicates a R^2 that is low and thus is less accurate at predicting

Table A7. Trend Statistics for the Susquehanna River at Towanda, Pa., October 1988 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.026	<0.001	-47	-44	-41	41-47	Down
DN	602	FAC	-0.023	<0.001	-44	-41	-37	37-44	Down
TON	605	FAC	-0.029	<0.001	-53	-47	-41	51-53	Down
DON	607	FAC	-0.022	<0.001	-46	-38	-30	30-46	Down
DNH_3	608	FAC	-0.020	<0.001	-46	-36	-24	N/A	BMDL
TNH_3	610	FAC	-0.029	<0.001	-56	-48	-37	37-56	Down
DKN	623	FAC	-0.021	<0.001	-45	-38	-30	30-45	Down
TKN	625	FAC	-0.029	<0.001	-53	-47	-41	41-53	Down
TNOx	630	FAC	-0.024	<0.001	-45	-41	-37	37-45	Down
DNOx	631	FAC	-0.023	<0.001	-45	-41	-36	36-45	Down
TP	665	FAC	-0.002	0.491	-17	-5	9	N/A	NS
DP	666	FAC	-0.003	0.354	-19	-7	8	N/A	NS
DOP	671	FAC	0.094	<0.001	469	618	806	469-806	Up
TOC	680	FAC	-0.004	0.002	-13	-8	-3	3-13	Down
SS	80154	FAC	-0.018	<0.001	-46	-33	-16	16-46	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: DANVILLE

Table A8. 2010 Annual and Seasonal Precipitation and Discharge at Danville

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	Discharge	LTM	% LTM
January-March (Winter)	8.71	7.74	0.97	23,467	22,820	103%
April-June (Spring)	9.71	10.73	-1.02	13,372	20,905	64%
July-September (Summer)	10.17	11.38	-1.21	3,379	6,628	51%
October-December (Fall)	12.59	9.37	3.22	22,223	15,647	142%
Annual Total	41.18	39.22	1.96	15,531	16,457	94%

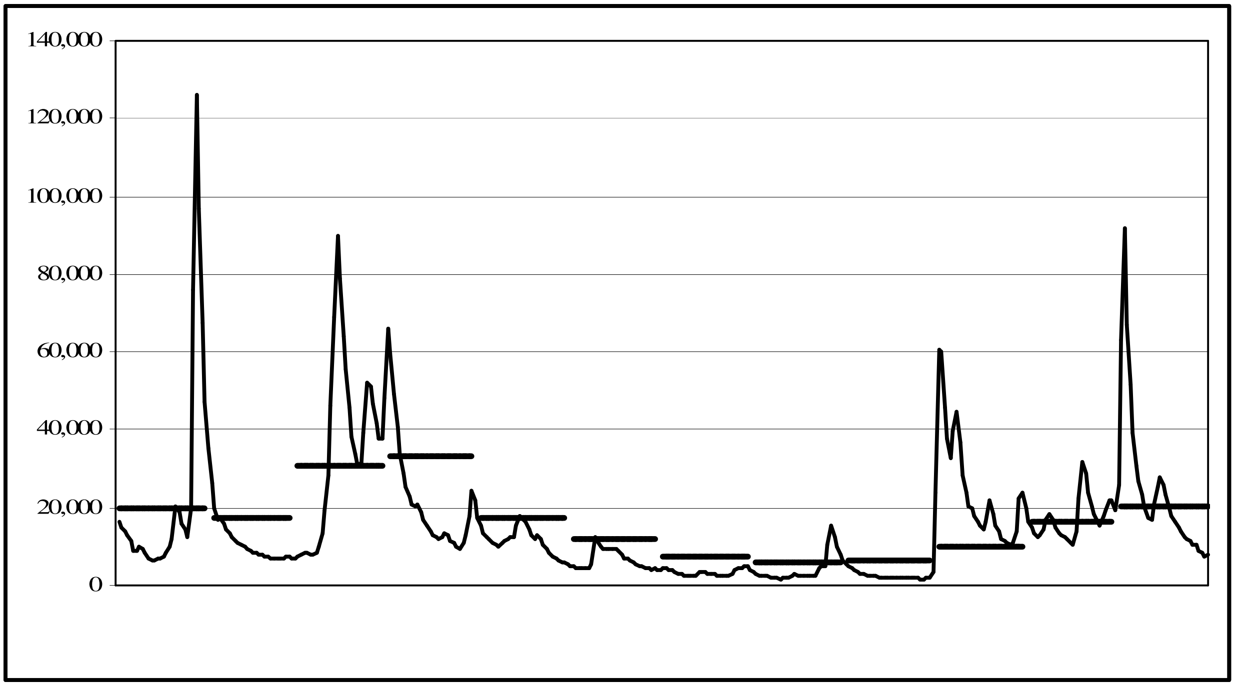

Figure A2. 2010 Daily Average Flow and Monthly LTM at Danville

Table A9. 2010 Annual Loads, Yields, and Concentrations at Danville

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/acre/yr	LTM Yield lb/acre/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	31,266	73	4	4.35	5.97	1.02	77
TP	2,990	83	10	0.42	0.50	0.10	88
SS	2,268,640	68	14	316	464	74	72
TNH_3	1,186	57	13	0.17	0.29	0.04	61
TNO_{23}	16,857	66	5	2.35	3.53	0.55	71
TON	11,298	72	7	1.57	2.19	0.37	76
DN	27,326	75	4	3.81	5.08	0.90	80
DNH_3	1,100	61	14	0.15	0.25	0.04	65
DNO_{23}	16,832	67	5	2.34	3.50	0.55	71
DON	7,384	76	7	1.03	1.36	0.24	80
DP	979	91	13	0.136	0.149	0.032	97
DOP	771	126	17	0.107	0.085	0.025	134
TOC	98,024	86	4	13.65	15.92	3.21	91

Table A10. 2010 Seasonal Loads and Yields at Danville

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	12,986	1.81	6,232	0.87	1,227	0.17	10,821	1.51
TNOx	7,381	1.028	3,103	0.432	468	0.065	5,905	0.822
TON	4,246	0.591	2,448	0.341	749	0.104	3,856	0.537
TNH_3	528	0.074	223	0.031	45	0.006	390	0.054
DN	11,365	1.58	5,421	0.75	979	0.14	9,560	1.33
DNOx	7,374	1.027	3,093	0.431	464	0.065	5,901	0.822
DON	2,722	0.379	1,584	0.221	464	0.065	2,615	0.364
DNH_3	500	0.070	202	0.028	40	0.006	357	0.050
TP	1,230	0.171	518	0.072	109	0.015	1,133	0.158
DP	360	0.050	208	0.029	54	0.008	357	0.050
DOP	278	0.039	157	0.022	39	0.005	297	0.041
TOC	33,103	4.61	18,938	2.64	5,971	0.83	40,010	5.57
SS	1,057,647	147	248,733	35	23,861	3	938,399	131

Table A11. 2010 Monthly Flow, Loads, and Yields at Danville

MONTH	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	23,782	120%	4,672	0.65	96%	490	0.068	130%	516,042	71.9	158%
February	10,772	62%	1,783	0.25	46%	83	0.012	39%	18,617	2.6	16%
March	34,617	112%	6,531	0.91	89%	657	0.092	114%	522,988	72.8	97%
April	21,918	66%	3,657	0.51	50%	319	0.044	48%	191,437	26.7	25%
May	11,602	66%	1,725	0.24	48%	130	0.018	48%	39,877	5.6	17%
June	6,655	56%	850	0.12	41%	69	0.010	28%	17,419	2.4	4%
July	3,381	47%	409	0.06	34%	35	0.005	28%	5,792	0.8	6%
August	4,194	69%	515	0.07	51%	50	0.007	48%	14,440	2.0	24%
September	2,536	38%	303	0.04	27%	24	0.003	16%	3,629	0.5	2%
October	24,513	242%	3,642	0.51	182%	492	0.068	260%	447,990	62.4	364%
November	17,177	105%	2,698	0.38	76%	208	0.029	69%	89,305	12.4	48%
December	24,817	121%	4,482	0.62	94%	433	0.060	118%	401,104	55.9	179%
Annual#	15,497		31,266	4.35		2,990	0.416		2,268,640	315.9	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A12. 2010 Annual Comparison to Baselines at Danville

Parameter	2010	Period	Y'	Q ratio	R^2
TN	4.35	85-89	9.26	1.16	0.96*
		85-97	6.54	0.99	0.83*
		98-10	4.67	0.9	0.71*
		85-10	5.48	0.94	0.56*
TP	0.416	85-89	0.74	1.16	0.96*
		85-97	0.46	0.99	0.83*
		98-10	0.37	0.9	0.90*
		85-10	0.41	0.94	0.85*
SS	315.9	85-89	907	1.16	0.98*
		85-97	356	0.99	0.83*
		98-10	235	0.9	0.73*
		85-10	316	0.94	0.78*

Table A13. 2010 Annual and Seasonal Comparison to Initial Five-Year Baselines at Danville

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.39	1.00	2.92	1.81	0.97	0.203	0.171	0.98*	181	147
Spring	0.72	1.00	1.44	0.87	1.00	0.101	0.072	0.98	69	35
Summer	0.62	0.99	0.30	0.17	0.93	0.024	0.015	0.79	6	3
Fall	1.69	1.00	2.85	1.51	0.98	0.206	0.158	0.96*	233	131
Annual	1.16	0.96*	9.26	4.35	0.97	0.740	0.416	0.99	907	316

*indicates where an exponential regression was used instead of a linear regression as it yielded a higher R^2

Table A14. Trend Statistics for the Susquehanna River at Danville, Pa., October 1984 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.024	<0.001	-50	-47	-44	44-50	Down
DN	602	FAC	-0.020	<0.001	-45	-41	-38	38-45	Down
TON	605	FAC	-0.031	<0.001	-61	-55	-50	50-61	Down
DON	607	FAC	-0.022	<0.001	-51	-45	-38	38-51	Down
DNH_3	608	FAC	-0.025	<0.001	-56	-48	-37	N/A	BMDL
TNH_3	610	FAC	-0.029	<0.001	-61	-53	-44	44-61	Down
DKN	623	FAC	-0.022	<0.001	-50	-44	-38	38-50	Down
TKN	625	FAC	-0.031	<0.001	-61	-56	-51	51-61	Down
TNOx	630	FAC	-0.020	<0.001	-45	-41	-37	37-45	Down
DNOx	631	FAC	-0.020	<0.001	-46	-41	-37	37-46	Down
TP	665	FAC	-0.011	0.000	-35	-24	-13	13-34	Down
DP	666	FAC	-0.002	0.567	-19	-5	12	N/A	NS
DOP	671	FAC	0.086	<0.001	560	756	1,011	N/A	BMDL
TOC	680	FAC	-0.008	<0.001	-23	-19	-14	14-23	Down
SS	80154	FAC	-0.028	<0.001	-60	-52	-42	42-60	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: MARIETTA

Table A15. 2010 Annual and Seasonal Precipitation and Discharge at Marietta

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	Discharge	LTM	% LTM
January-March (Winter)	9.07	8.13	0.94	60,824	54,723	111%
April-June (Spring)	9.14	10.76	-1.62	31,922	48,768	65%
July-September (Summer)	10.97	11.53	-0.56	7,908	17,202	46%
October-December (Fall)	11.83	9.58	2.25	49,641	35,204	141%
Annual Total	41.01	40	1.01	37,359	38,872	96%

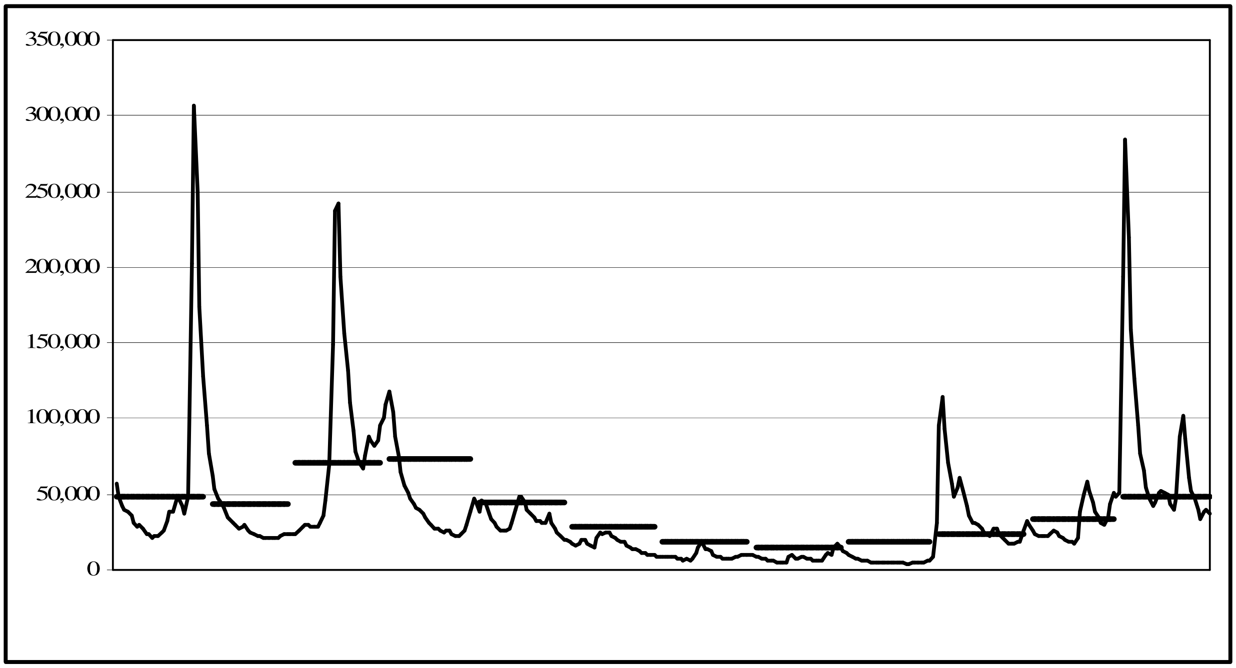

Figure A3. 2010 Daily Average Flow and Monthly LTM at Marietta

Table A16. 2010 Annual Loads, Yields, and Concentrations at Marietta

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/acre/yr	LTM Yield lb/acre/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	101,699	80	4	6.11	7.67	1.39	83
TP	6,073	82	8	0.37	0.45	0.08	85
SS	7,071,459	109	15	425	391	96	113
TNH_3	2,679	60	13	0.16	0.27	0.04	62
TNO_{23}	70,575	78	5	4.24	5.44	0.96	81
TON	29,624	88	9	1.78	2.03	0.40	92
DN	85,965	77	5	5.17	6.70	1.17	80
DNH_3	2,225	57	13	0.13	0.23	0.03	60
DNO_{23}	70,800	79	5	4.26	5.41	0.96	82
DON	14,479	76	10	0.87	1.14	0.20	79
DP	1,364	61	9	0.082	0.134	0.019	64
DOP	952	78	11	0.057	0.073	0.013	81
TOC	223,563	95	4	13.44	14.14	3.05	99

Table A17.   2010 Seasonal Loads and Yields at Marietta

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	42,500	2.56	18,720	1.13	3,934	0.24	36,545	2.20
TNOx	30,224	1.817	12,995	0.781	2,317	0.139	25,039	1.505
TON	11,741	0.706	5,523	0.332	1,683	0.101	10,677	0.642
TNH_3	1,256	0.076	443	0.027	103	0.006	877	0.053
DN	35,908	2.16	15,854	0.95	3,343	0.20	30,860	1.86
DNOx	30,237	1.818	13,023	0.783	2,330	0.140	25,210	1.516
DON	5,396	0.324	2,894	0.174	995	0.060	5,193	0.312
DNH_3	1,049	0.063	375	0.023	85	0.005	716	0.043
TP	2,566	0.154	791	0.048	180	0.011	2,537	0.153
DP	464	0.028	207	0.012	72	0.004	621	0.037
DOP	313	0.019	138	0.008	49	0.003	453	0.027
TOC	83,083	4.99	42,900	2.58	13,570	0.82	84,011	5.05
SS	3,402,434	205	553,242	33	51,615	3	3,064,169	184

Table A18.   2010 Monthly Flow, Loads, and Yields at Marietta

Month	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	65,368	133%	16,723	1.01	109%	1,136	0.068	143%	1,615,621	97.1	210%
February	31,336	73%	6,731	0.40	58%	165	0.010	38%	80,925	4.9	30%
March	82,916	117%	19,046	1.15	96%	1,264	0.076	110%	1,705,887	102.6	165%
April	45,247	61%	9,294	0.56	48%	401	0.024	31%	335,421	20.2	29%
May	33,532	75%	6,530	0.39	58%	270	0.016	41%	165,810	10.0	28%
June	16,932	61%	2,895	0.17	46%	120	0.007	27%	52,010	3.1	12%
July	9,484	52%	1,562	0.09	38%	71	0.004	28%	22,592	1.4	15%
August	8,496	58%	1,452	0.09	42%	68	0.004	31%	20,098	1.2	14%
September	5,672	30%	921	0.06	19%	41	0.002	8%	8,926	0.5	1%
October	39,016	167%	9,092	0.55	134%	609	0.037	155%	518,990	31.2	181%
November	31,223	92%	7,335	0.44	73%	281	0.017	53%	149,056	9.0	43%
December	78,090	162%	20,118	1.21	133%	1,647	0.099	212%	2,396,124	144.1	413%
Annual#	37,276		101,699	6.11		6,073	0.365		7,071,459	425.1	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A19. 2010 Annual Comparison to Baselines at Marietta

Parameter	2010	Period	Y'	Q ratio	R^2
TN	6.11	87-91	10.1	1.12	1.00
		87-98	7.9	0.97	0.94
		99-10	6.81	0.95	0.96
		85-10	7.35	0.96	0.90
TP	0.365	87-91	0.51	1.12	0.79
		87-98	0.44	0.97	0.90
		99-10	0.4	0.95	0.79
		85-10	0.42	0.96	0.85
SS	425.1	87-91	423	1.12	0.70
		87-98	363	0.97	0.88
		99-10	347	0.95	0.67
		85-10	356	0.96	0.77

Table A20. 2010 Annual and Seasonal Comparison to Initial Five-Year Baselines at Marietta

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.37	1.00	3.57	2.56	0.87	0.136	0.154	0.97	91	205
Spring	0.69	1.00	1.62	1.13	0.91	0.080	0.048	0.92	45	33
Summer	0.54	1.00	0.36	0.24	0.89*	0.015	0.011	0.91*	3	3
Fall	1.69	1.00	3.20	2.20	1.00	0.168	0.153	0.98	150	184
Annual	1.12	1.00	10.10	6.11	0.79	1.120	0.365	0.70	423	425

Table A21. Trend Statistics for the Susquehanna River at Marietta, Pa., October 1986 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.014	<0.001	-34	-30	-25	25-34	Down
DN	602	FAC	-0.024	<0.001	-47	-44	-40	40-47	Down
TON	605	FAC	-0.028	<0.001	-56	-49	-41	41-56	Down
DON	607	FAC	-0.025	<0.001	-53	-46	-37	37-53	Down
DNH_3	608	FAC	-0.015	<0.001	-42	-31	-18	18-42	BMDL
TNH_3	610	FAC	-0.017	<0.001	-44	-33	-21	21-44	Down
DKN	623	FAC	-0.023	<0.001	-50	-42	-34	34-50	Down
TKN	625	FAC	-0.026	<0.001	-54	-47	-40	40-54	Down
TNOx	630	FAC	-0.007	<0.001	-22	-16	-10	10-22	Down
DNOx	631	FAC	-0.007	<0.001	-22	-16	-10	10-22	Down
TP	665	FAC	-0.014	<0.001	-37	-28	-18	18-37	Down
DP	666	FAC	-0.021	<0.001	-48	-40	-31	31-48	Down
DOP	671	FAC	0.086	<0.001	460	623	831	N/A	BMDL
TOC	680	FAC	-0.006	<0.001	-19	-14	-8	8-19	Down
SS	80154	FAC	-0.019	<0.001	-48	-36	-22	22-48	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: LEWISBURG

Table A22. 2010 Annual and Seasonal Precipitation and Discharge at Lewisburg

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	Discharge	LTM	% LTM
January-March (Winter)	9.08	8.29	0.79	16,443	15,262	108%
April-June (Spring)	8.9	10.97	-2.07	8,219	12,720	65%
July-September (Summer)	11.32	12.4	-1.08	1,738	4,996	35%
October-December (Fall)	12.79	9.82	2.97	13,180	10,128	130%
Annual Total	42.09	41.48	0.61	9,837	10,749	92%

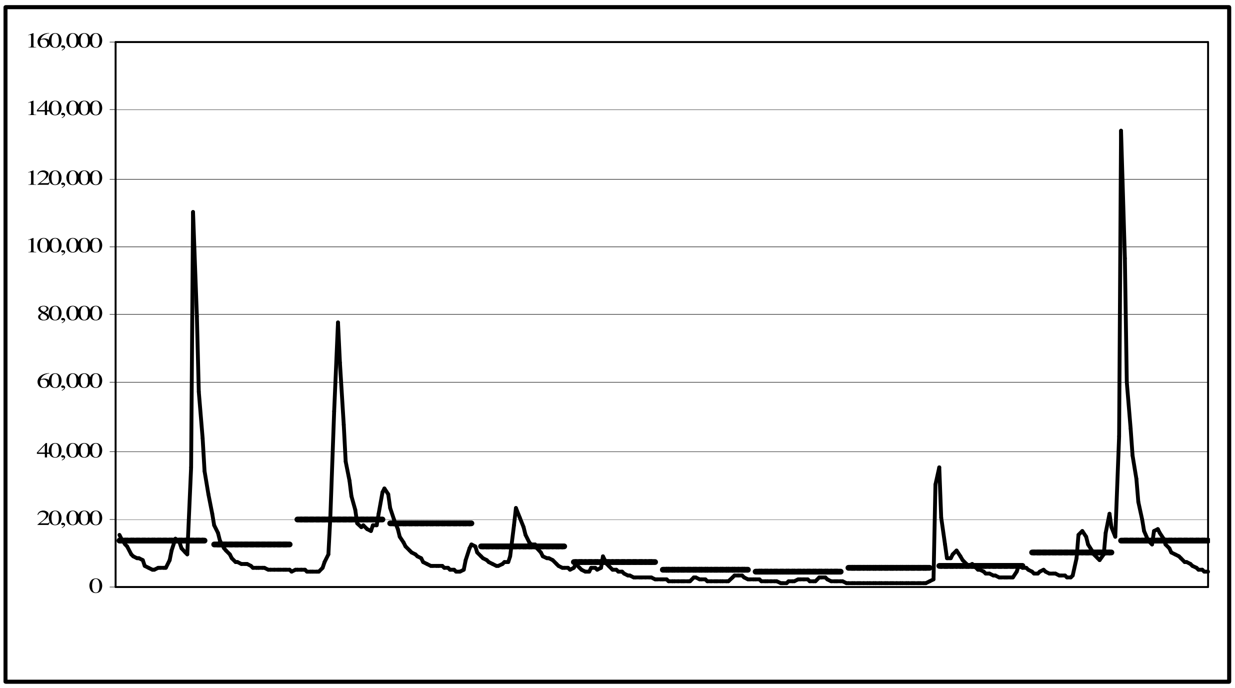

Figure A4. 2010 Daily Average Flow and Monthly LTM at Lewisburg

Table A23.   2010 Annual Loads, Yields, and Concentrations at Lewisburg

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/ac/yr	LTM Yield lb/ac/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	15,893	69	5	3.63	5.23	0.82	76
TP	858	70	13	0.20	0.28	0.04	76
SS	979,204	86	20	223	261	51	94
TNH_3	516	50	13	0.12	0.24	0.03	55
TNO_{23}	10,440	70	4	2.38	3.40	0.54	77
TON	4,910	68	13	1.12	1.65	0.25	74
DN	14,343	71	4	3.27	4.64	0.74	77
DNH_3	489	55	12	0.11	0.20	0.03	60
DNO_{23}	10,415	71	4	2.38	3.37	0.54	77
DON	3,560	73	11	0.81	1.12	0.18	80
DP	261	55	18	0.059	0.107	0.014	61
DOP	202	89	22	0.046	0.052	0.010	97
TOC	41,838	93	5	9.55	10.24	2.17	102

Table A24. 2010 Seasonal Loads and Yields at Lewisburg

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	7,021	1.60	3,003	0.69	686	0.16	5,183	1.18
TNOx	4,683	1.069	2,004	0.457	421	0.096	3,333	0.760
TON	2,070	0.472	828	0.189	240	0.055	1,772	0.404
TNH_3	242	0.055	99	0.023	22	0.005	153	0.035
DN	6,320	1.44	2,816	0.64	636	0.15	4,571	1.04
DNOx	4,675	1.067	1,996	0.455	420	0.096	3,325	0.759
DON	1,465	0.334	702	0.160	203	0.046	1,190	0.272
DNH_3	239	0.055	95	0.022	19	0.004	136	0.031
TP	386	0.088	138	0.031	24	0.005	311	0.071
DP	109	0.025	68	0.015	14	0.003	70	0.016
DOP	86	0.020	56	0.013	10	0.002	50	0.011
TOC	16,066	3.67	6,998	1.60	1,918	0.44	16,857	3.85
SS	411,374	94	56,397	13	3,643	1	507,790	116

Table A25. 2010 Monthly Flow, Loads, and Yields at Lewisburg

Monthly	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	19,573	144%	2,980	0.68	109%	176	0.040	119%	228,253	52.1	119%
February	7,997	66%	1,125	0.26	51%	33	0.008	37%	11,408	2.6	19%
March	20,942	106%	2,916	0.67	79%	176	0.040	87%	171,712	39.2	83%
April	9,999	53%	1,285	0.29	38%	55	0.012	27%	23,577	5.4	10%
May	10,012	85%	1,191	0.27	62%	60	0.014	60%	26,952	6.2	33%
June	4,587	62%	526	0.12	47%	23	0.005	39%	5,868	1.3	19%
July	2,178	45%	275	0.06	36%	10	0.002	25%	1,728	0.4	10%
August	1,892	42%	246	0.06	35%	9	0.002	20%	1,380	0.3	4%
September	1,123	20%	165	0.04	19%	5	0.001	8%	535	0.1	1%
October	7,993	124%	954	0.22	85%	48	0.011	80%	34,542	7.9	83%
November	8,237	79%	1,067	0.24	55%	39	0.009	39%	19,354	4.4	24%
December	23,151	172%	3,162	0.72	124%	224	0.051	183%	453,893	103.6	491%
Annual#	9,807		15,893	3.63		858	0.196		979,204	223.5	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A26. 2010 Annual Comparison to Baselines at Lewisburg

Parameter	2010	Period	Y'	Q ratio	R^2
TN	3.63	85-89	6.08	0.99	0.91
		85-97	5.13	0.88	0.94
		98-10	4.36	0.94	0.94
		85-10	4.75	0.91	0.81
TP	0.196	85-89	0.28	0.99	0.93*
		85-97	0.23	0.88	0.90*
		98-10	0.24	0.94	0.91*
		85-10	0.23	0.91	0.87*
SS	223.5	85-89	185	0.99	0.71*
		85-97	143	0.88	0.83*
		98-10	194	0.94	0.63*
		85-10	153	0.91	0.72*

Table A27. 2010 Annual and Seasonal Comparison to Initial Five-Year Baselines at Lewisburg

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.26	0.99	2.51	1.60	0.99*	0.099	0.088	0.95*	85	94
Spring	0.61	1.00	1.15	0.69	0.99	0.049	0.031	0.96	15	13
Summer	0.42	0.99	0.23	0.16	0.97	0.013	0.005	0.41#	2	1
Fall	1.42	1.00	1.98	1.18	0.99	0.086	0.071	0.97*	51	116
Annual	0.99	0.91	6.08	3.63	0.93*	0.280	0.196	0.71*	185	224

Table A28. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., October 1984 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.017	<0.001	-40	-36	-31	31-40	Down
DN	602	FAC	-0.014	<0.001	-36	-31	-27	27-36	Down
TON	605	FAC	-0.037	<0.001	-69	-63	-56	56-69	Down
DON	607	FAC	-0.031	<0.001	-62	-56	-48	48-62	Down
DNH_3	608	FAC	-0.015	<0.001	-44	-33	-19	N/A	BMDL
TNH_3	610	FAC	-0.020	<0.001	-51	-42	-30	N/A	BMDL
DKN	623	FAC	-0.022	<0.001	-51	-44	-37	37-51	Down
TKN	625	FAC	-0.031	<0.001	-62	-56	-49	49-62	Down
TNOx	630	FAC	-0.007	<0.001	-22	-17	-11	11-22	Down
DNOx	631	FAC	-0.007	<0.001	-22	-17	-11	11-22	Down
TP	665	FAC	-0.017	<0.001	-47	-36	-24	24-47	Down
DP	666	FAC	-0.028	<0.001	-61	-52	-42	N/A	BMDL
DOP	671	FAC	0.064	<0.001	267	401	584	N/A	BMDL
TOC	680	FAC	0.002	0.192	-2	5	14	N/A	NS
SS	80154	FAC	-0.016	<0.001	-48	-34	-16	16-48	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: NEWPORT

Table A29. 2010 Annual and Seasonal Precipitation and Discharge at Newport

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	Discharge	LTM	% LTM
January-March (Winter)	9.5	7.67	1.83	8,519	6,492	131%
April-June (Spring)	8.79	9.93	-1.14	4,127	5,415	76%
July-September (Summer)	10.28	10.03	0.25	1,085	1,952	56%
October-December (Fall)	11.97	9.17	2.8	4,137	3,692	112%
Annual Total	40.54	36.8	3.74	4,434	4,375	101%

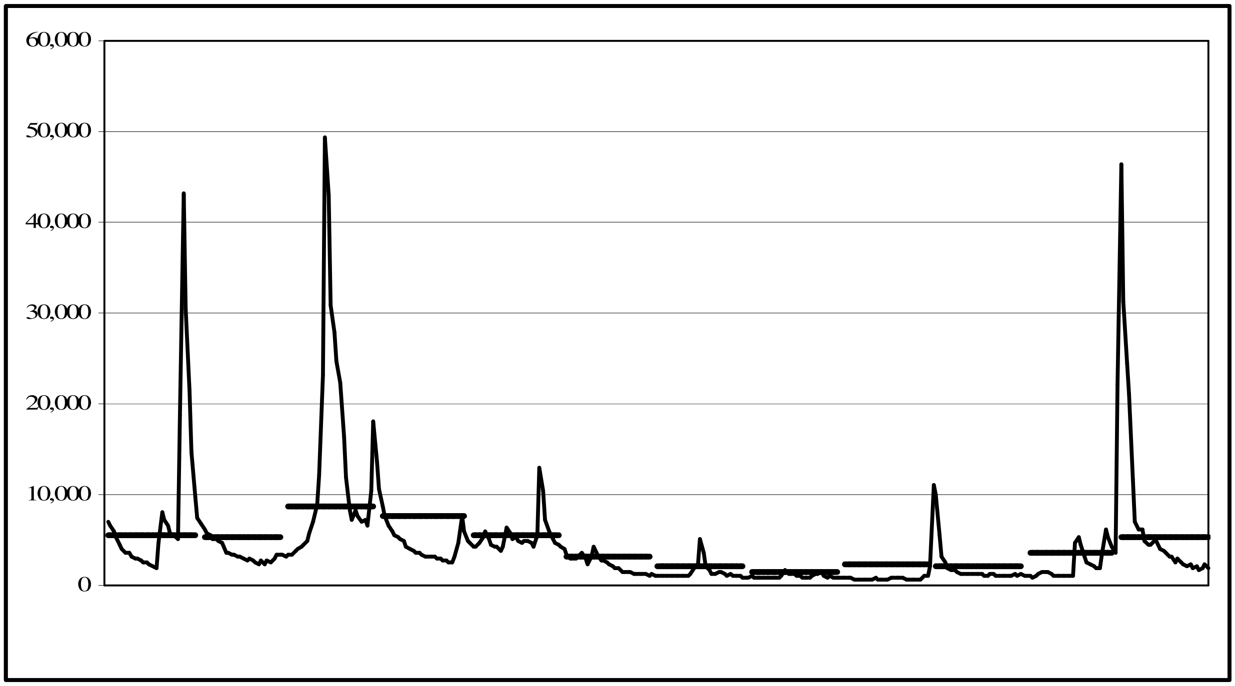

Figure A5. 2010 Daily Average Flow and Monthly LTM at Newport

Table A30. 2010 Annual Loads, Yields, and Concentrations at Newport

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/ac/yr	LTM Yield lb/ac/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	14,148	88	3	6.59	7.49	1.63	87
TP	634	83	10	0.30	0.36	0.07	82
SS	533,831	105	18	249	236	61	104
TNH_3	235	63	13	0.11	0.17	0.03	62
TNO_{23}	10,479	88	3	4.88	5.58	1.20	87
TON	3,536	91	13	1.65	1.81	0.41	90
DN	12,680	87	3	5.91	6.77	1.46	86
DNH_3	185	57	14	0.09	0.15	0.02	57
DNO_{23}	10,498	88	3	4.89	5.53	1.21	87
DON	1,956	79	9	0.91	1.15	0.22	78
DP	216	60	9	0.100	0.168	0.025	59
DOP	167	79	11	0.078	0.098	0.019	78
TOC	27,570	99	5	12.84	12.96	3.17	98

Table A31. 2010 Monthly Flow, Loads, and Yields at Newport

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	6,989	3.26	2,964	1.38	629	0.29	3,565	1.66
TNOx	5,149	2.399	2,283	1.064	442	0.206	2,605	1.213
TON	1,803	0.840	651	0.303	193	0.090	889	0.414
TNH_3	117	0.054	51	0.024	16	0.008	51	0.024
DN	6,167	2.87	2,747	1.28	587	0.27	3,179	1.48
DNOx	5,154	2.401	2,288	1.066	440	0.205	2,616	1.218
DON	885	0.412	425	0.198	141	0.066	505	0.235
DNH_3	90	0.042	41	0.019	13	0.006	40	0.019
TP	299	0.139	101	0.047	31	0.014	204	0.095
DP	86	0.040	44	0.020	18	0.008	68	0.032
DOP	66	0.031	32	0.015	13	0.006	56	0.026
TOC	12,610	5.87	5,669	2.64	1,854	0.86	7,437	3.46
SS	296,950	138	45,420	21	6,457	3	185,003	86

Table A32. 2010 Monthly Flow, Loads, and Yields at Newport

Month	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	8,155	150%	2,471	1.15	135%	97	0.045	146%	83,677	39.0	205%
February	3,730	71%	934	0.44	60%	17	0.008	32%	4,866	2.3	20%
March	13,209	153%	3,584	1.67	136%	185	0.086	159%	208,407	97.1	248%
April	4,640	61%	1,135	0.53	52%	31	0.014	30%	12,970	6.0	18%
May	5,361	99%	1,332	0.62	87%	51	0.024	64%	26,411	12.3	54%
June	2,340	74%	497	0.23	60%	19	0.009	38%	6,040	2.8	21%
July	1,434	71%	292	0.14	53%	14	0.007	41%	3,814	1.8	18%
August	1,009	69%	192	0.09	50%	10	0.005	45%	1,659	0.8	26%
September	804	34%	146	0.07	20%	7	0.003	10%	984	0.5	1%
October	2,113	97%	558	0.26	78%	28	0.013	78%	12,478	5.8	66%
November	2,348	65%	628	0.29	50%	19	0.009	32%	5,188	2.4	15%
December	7,892	150%	2,379	1.11	127%	157	0.073	210%	167,337	78.0	403%
Annual#	4,420		14,148	6.59		634	0.295		533,831	248.7	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A33. 2010 Annual Comparison to Baselines at Newport

Parameter	2010	Period	Y'	Q ratio	R^2
TN	6.59	85-89	9.11	1.12	0.84
		85-97	7.54	0.99	0.95
		98-10	7.63	1.03	0.98
		85-10	7.57	1.01	0.96
TP	0.295	85-89	0.54	1.12	0.68
		85-97	0.37	0.99	0.75
		98-10	0.36	1.03	0.83
		85-10	0.36	1.01	0.78
SS	248.7	85-89	364	1.12	0.94
		85-97	226	0.99	0.90
		98-10	264	1.03	0.73
		85-10	242	1.01	0.77

Table A34. 2010 Annual and Seasonal Comparison to Initial Five-Year Baselines at Newport

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.61	0.96	4.25	3.26	0.84	0.255	0.139	0.83*	272	138
Spring	0.73	0.98	1.83	1.38	0.89	0.119	0.047	0.98	64	21
Summer	0.54	1.00	0.40	0.29	1.00	0.028	0.014	1.00	3	3
Fall	1.36	1.00	2.41	1.66	1.00*	0.121	0.095	0.99*	52	86
Annual	1.12	0.84	9.11	6.59	0.68	0.540	0.295	0.94	364	249

* indicates where an exponential regression was used instead of a linear regression as it yielded a higher R^2

Table A35. Trend Statistics for the Juniata River at Newport, Pa., October 1984 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.006	<0.001	-19	-15	-10	10-19	Down
DN	602	FAC	-0.004	<0.001	-15	-10	-5	5-15	Down
TON	605	FAC	-0.030	<0.001	-62	-55	-47	47-62	Down
DON	607	FAC	-0.025	<0.001	-54	-48	-41	41-54	Down
DNH_3	608	FAC	-0.019	<0.001	-50	-39	-27	27-50	BMDL
TNH_3	610	FAC	-0.018	<0.001	-48	-38	-26	26-48	BMDL
DKN	623	FAC	-0.026	<0.001	-56	-49	-41	41-56	Down
TKN	625	FAC	-0.027	<0.001	-58	-51	-43	43-58	Down
TNOx	630	FAC	0.000	0.849	-5	-1	5	N/A	NS
DNOx	631	FAC	0.001	0.428	-3	2	8	N/A	NS
TP	665	FAC	-0.020	<0.001	-50	-42	-32	32-50	Down
DP	666	FAC	-0.022	<0.001	-51	-44	-35	35-51	Down
DOP	671	FAC	0.040	<0.001	114	178	260	114-260	Up
TOC	680	FAC	-0.007	<0.001	-24	-18	-10	10-24	Down
SS	80154	FAC	-0.018	<0.001	-50	-37	-21	21-50	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: CONESTOGA

Table A36. 2010 Annual and Seasonal Precipitation and Discharge at Conestoga

Season	2010 Annual Precipitation	Annual Precipitation LTM	Departure From LTM	Discharge	LTM	% LTM
January-March (Winter)	8.63	8.72	-0.09	964	895	108%
April-June (Spring)	9.26	10.82	-1.56	627	721	87%
July-September (Summer)	9.69	12.58	-2.89	335	458	73%
October-December (Fall)	12.11	10.69	1.42	667	631	106%
Annual Total	39.69	42.81	-3.12	645	675	96%

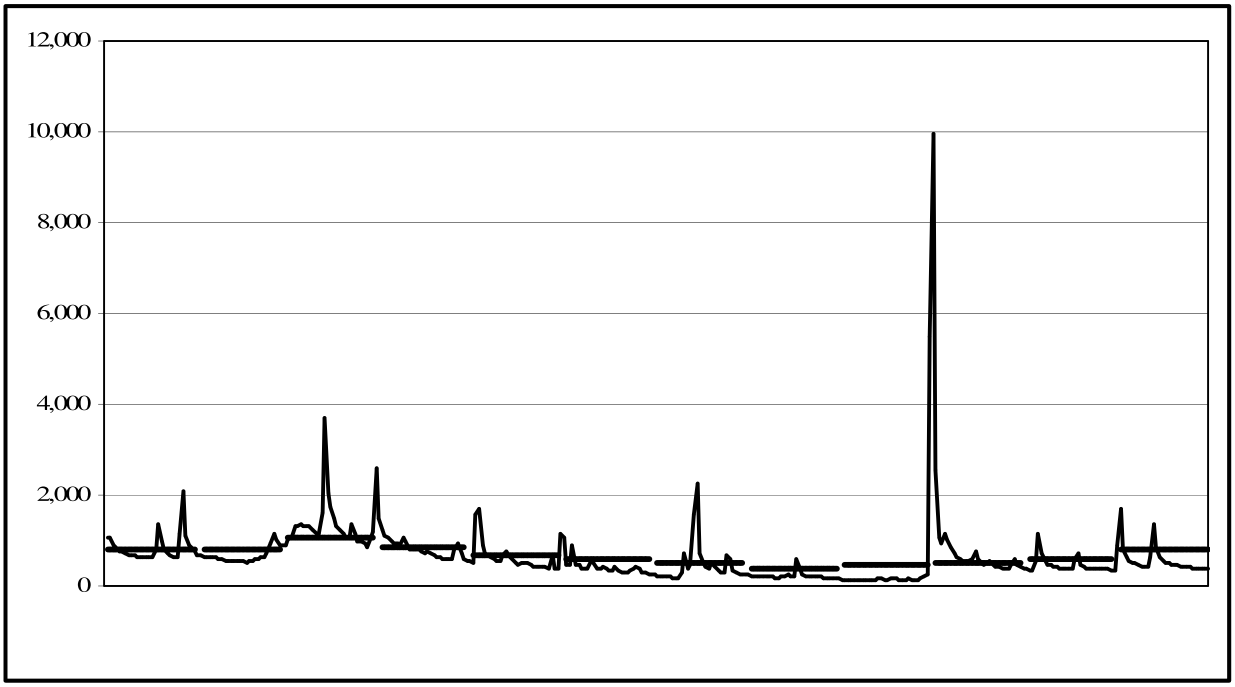

Figure A6. 2010 Daily Average Flow and Monthly LTM at Conestoga

Table A37. 2010 Annual Loads, Yields, and Concentrations at Conestoga

Parameter	Load 1000's of lbs	Load % of LTM	Error %	Yield lbs/acre/yr	LTM Yield lb/acre/yr	Ave. Conc. mg/L	Conc. % of LTM
TN	7,965	78	3	26.48	34.11	6.27	81
TP	415	65	10	1.38	2.13	0.33	68
SS	305,268	88	23	1,015	1,152	240	92
TNH_3	127	51	15	0.42	0.82	0.10	54
TNO_{23}	6,849	82	5	22.77	27.71	5.39	86
TON	902	49	11	3.00	6.11	0.71	51
DN	7,522	79	4	25.01	31.48	5.92	83
DNH_3	118	52	15	0.39	0.75	0.09	55
DNO_{23}	6,815	83	5	22.66	27.20	5.36	87
DON	551	48	10	1.83	3.78	0.43	51
DP	186	75	8	0.619	0.829	0.146	78
DOP	153	74	8	0.508	0.684	0.120	78
TOC	5,325	72	5	17.70	24.49	4.19	76

Table A38. 2010 Monthly Flow, Loads, and Yields at Conestoga

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	3,141	10.44	1,887	6.27	923	3.07	2,013	6.69
TNOx	2,693	8.952	1,625	5.401	793	2.635	1,739	5.782
TON	360	1.197	206	0.686	104	0.346	231	0.768
TNH_3	49	0.163	26	0.085	15	0.050	38	0.125
DN	2,975	9.89	1,803	5.99	866	2.88	1,879	6.25
DNOx	2,669	8.873	1,614	5.366	790	2.627	1,742	5.790
DON	231	0.769	148	0.493	62	0.205	110	0.366
DNH_3	47	0.156	24	0.080	13	0.044	34	0.112
TP	83	0.275	58	0.194	77	0.256	197	0.655
DP	42	0.140	32	0.107	38	0.128	73	0.244
DOP	33	0.111	26	0.086	32	0.107	61	0.203
TOC	1,677	5.57	1,182	3.93	834	2.77	1,632	5.43
SS	43,360	144	21,974	73	50,830	169	189,104	629

Table A39. 2010 Monthly Flow, Loads, and Yields at Conestoga

Month	Flow		TN			TP			SS		
	2010	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	841	105%	998	3.32	91%	23	0.075	41%	7,523	25.0	30%
February	666	83%	709	2.36	69%	13	0.044	28%	3,887	12.9	21%
March	1,355	127%	1,435	4.77	101%	47	0.156	53%	31,950	106.2	53%
April	828	95%	847	2.82	76%	23	0.076	42%	9,833	32.7	37%
May	636	92%	641	2.13	70%	21	0.070	43%	8,716	29.0	29%
June	417	70%	399	1.33	58%	14	0.047	26%	3,425	11.4	10%
July	456	87%	431	1.43	69%	24	0.081	49%	10,375	34.5	32%
August	222	58%	218	0.72	48%	10	0.032	33%	894	3.0	9%
September	327	70%	275	0.91	52%	43	0.143	75%	39,560	131.5	102%
October	965	195%	879	2.92	148%	161	0.534	329%	179,908	598.1	705%
November	454	77%	487	1.62	66%	16	0.054	36%	3,116	10.4	19%
December	576	72%	647	2.15	62%	20	0.067	32%	6,081	20.2	23%
Annual#	645		7,965	26.48		415	1.380		305,268	1,014.9	

# indicates a R^2 that is low and thus is less accurate at predicting

Table A40. 2010 Annual Comparison to Baselines at Conestoga

Parameter	2010	Period	Y'	Q ratio	R^2
TN	26.48	85-89	38	1.03	0.99
		85-97	34.8	0.97	0.98
		98-10	30.7	0.94	0.96
		85-10	32.7	0.96	0.95
TP	1.38	85-89	2.67	1.03	0.67
		85-97	2.46	0.97	0.90
		98-10	1.62	0.94	0.52
		85-10	2.01	0.96	0.61
SS	1,015	85-89	1533	1.03	0.87
		85-97	1243	0.97	0.90
		98-10	948	0.94	0.30
		85-10	1069	0.96	0.55

Table A41. 2010 Annual and Seasonal Comparison to Initial 5-Year Baselines at Conestoga

Time Period	Flow Ratio	TN			TP			SS		
		R^2	Y'	Y10	R^2	Y'	Y10	R^2	Y'	Y10
Winter	1.27	1.00*	17.42	10.44	0.45*#	0.874	0.275	0.25*#	268	144
Spring	0.89	1.00	8.93	6.27	0.99	0.584	0.194	0.98	321	73
Summer	0.61	1.00	4.28	3.07	0.21#	0.574	0.256	0.16#	382	169
Fall	1.29	0.98	8.85	6.69	0.85	0.660	0.655	0.95	189	629
Annual	1.03	0.99	38.00	26.48	0.72*	2.660	1.380	0.87	1,533	1,015

* indicates where an exponential regression was used instead of a linear regression as it yielded a higher R^2
# indicates a R^2 that is low and thus is less accurate at predicting

Table A42. Trend Statistics for the Conestoga River at Conestoga, Pa., October 1984 Through September 2010

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK			-	-	-	-	NS
TN	600	FAC	-0.010	<0.001	-26	-22	-19	19-26	Down
DN	602	FAC	-0.002	0.014	-10	-6	-1	1-10	Down
TON	605	FAC	-0.031	<0.001	-62	-56	-50	50-62	Down
DON	607	FAC	-0.007	0.004	-27	-17	-6	6-27	Down
DNH_3	608	FAC	-0.055	<0.001	-81	-77	-73	73-80	Down
TNH_3	610	FAC	-0.057	<0.001	-81	-78	-74	74-81	Down
DKN	623	FAC	-0.016	<0.001	-41	-34	-25	25-41	Down
TKN	625	FAC	-0.037	<0.001	-67	-62	-57	57-67	Down
TNOx	630	FAC	0.000	0.720	-7	-1	5	N/A	NS
DNOx	631	FAC	0.000	0.850	-5	1	7	N/A	NS
TP	665	FAC	-0.031	<0.001	-61	-56	-50	50-61	Down
DP	666	FAC	-0.025	<0.001	-52	-48	-43	43-52	Down
DOP	671	FAC	-0.011	<0.001	-35	-25	-14	14-35	Down
TOC	680	FAC	-0.025	<0.001	-53	-49	-44	44-53	Down
SS	80154	FAC	-0.048	<0.001	-78	-72	-66	66-78	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

APPENDIX B

Summary Statistics

Table B1. Temperature, Dissolved Oxygen, Conductivity, and pH Summary Statistics of Samples Collected During 2010

Station	Temperature (C°)					Dissolved Oxygen (mg/L)					Conductivity (umhos/cm)					pH (S.U.)				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.10	25	8.61	9.27	7.84	7.71	13.80	10.83	10.79	1.94	136	509	288	285	120	7.0	8.3	7.8	7.7	0.49
Cohocton	0.10	25	6.20	8.81	8.30	7.56	13.80	11.12	10.98	1.82	157	751	380	373	178	6.9	8.5	7.8	7.7	0.56
Conklin	0.10	27	8.64	10.68	8.77	7.51	13.44	10.52	10.55	1.94	94	235	159	160	45	7.0	8.6	7.8	7.7	0.49
Smithboro	0.10	26	8.52	9.34	7.83	7.85	12.91	11.02	10.71	1.62	93	349	182	185	71	6.9	8.7	7.7	7.6	0.51
Unadilla	0.10	26	7.81	10.04	8.70	8.22	13.66	11.04	10.91	1.66	129	314	204	206	61	7.0	8.3	7.8	7.6	0.42
Castanea	0.79	23	9.53	11.26	7.59	7.17	16.80	11.35	11.34	2.35	104	435	232	251	109	6.8	8.4	7.7	7.6	0.47
Conestoga	0.69	28	10.14	13.75	8.21	5.84	16.46	9.77	10.20	2.32	131	812	579	564	176	6.8	8.8	8.0	8.0	0.38
Danville	0.10	28	7.80	10.95	9.26	6.92	13.98	11.75	10.94	1.90	111	386	191	205	79	6.8	8.4	7.6	7.5	0.41
Dromgold	-0.06	28	10.03	13.05	7.32	7.55	13.77	10.40	10.41	1.79	93	261	116	143	56	6.9	8.3	7.7	7.6	0.43
Hershey	-0.06	28	8.31	11.10	8.08	6.13	13.10	10.36	10.03	2.14	142	500	296	304	103	7.0	8.4	7.7	7.7	0.42
Hogestown	-0.07	26	11.22	13.45	7.44	6.78	15.17	10.02	10.11	2.32	169	547	309	347	133	7.1	8.4	7.7	7.7	0.37
Jersey Shore	0.07	28	7.49	10.25	8.32	7.76	17.18	11.42	11.61	2.43	61	430	205	206	114	6.3	8.2	7.2	7.2	0.55
Karthaus	0.30	26	8.06	10.38	8.27	7.41	14.63	11.61	10.99	1.98	137	788	350	367	191	6.0	7.2	6.8	6.7	0.35
Lewisburg	0.10	29	7.69	11.30	9.08	7.58	16.96	11.34	11.44	2.40	71	374	179	184	87	6.5	8.5	7.3	7.3	0.50
Manchester	-0.06	24	13.30	12.72	7.58	6.20	16.09	9.46	9.87	2.43	125	403	268	270	70	6.2	8.2	7.7	7.7	0.43
Marietta	-0.13	30	9.59	13.18	8.67	7.49	14.71	10.58	10.98	2.24	109	348	203	220	72	6.9	9.0	7.9	7.9	0.53
Martic Forge	-0.08	27	9.30	10.91	6.62	5.95	16.44	10.30	10.66	2.70	174	547	452	423	101	7.5	8.3	8.0	7.9	0.24
Newport	-0.07	31	9.95	12.99	8.93	7.04	16.78	11.01	11.01	2.21	135	344	227	236	67	7.0	9.0	8.1	8.0	0.57
Penns Creek	-0.05	31	9.80	11.41	8.74	7.57	16.95	11.39	11.63	2.61	102	273	175	182	49	7.0	9.3	8.0	7.9	0.54
Saxton	3.36	32	13.80	14.95	9.19	4.38	14.77	8.72	8.47	3.31	122	393	279	260	84	6.7	8.6	7.6	7.6	0.62
Towanda	0.10	27	8.01	10.39	8.75	7.24	13.65	10.66	10.47	1.84	113	366	207	201	65	6.9	8.7	7.8	7.6	0.48
Wilkes-Barre	0.10	27	6.46	10.19	9.28	7.38	13.18	11.11	10.77	1.81	112	385	230	218	93	6.9	8.0	7.6	7.5	0.44
Richardsmere	0.00	23	9.05	11.93	7.58	6.03	16.20	10.68	11.02	2.62	207	281	253	246	19	6.6	9.0	7.8	7.8	0.54

Table B2. Total Nitrogen Species Summary Statistics of Samples Collected During 2010, in mg/L

Station	Total Nitrogen					Total Ammonium					Total Nitrate plus Nitrite					Total Organic Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.63	3.91	1.06	1.28	0.71	0.01	0.12	0.05	0.05	0.04	0.25	1.17	0.52	0.54	0.23	0.19	3.54	0.43	0.68	0.77
Cohocton	0.94	8.66	1.69	2.34	1.83	0.01	0.17	0.03	0.05	0.04	0.51	8.33	1.05	1.36	1.72	0.21	3.84	0.68	0.93	0.98
Conklin	0.52	1.48	0.63	0.72	0.23	0.01	0.13	0.04	0.04	0.03	0.09	0.49	0.31	0.32	0.10	0.06	1.13	0.32	0.36	0.24
Smithboro	0.56	5.99	0.76	1.06	1.18	0.01	0.09	0.02	0.03	0.03	0.01	0.86	0.37	0.40	0.17	0.08	5.52	0.30	0.63	1.17
Unadilla	0.58	1.38	0.85	0.88	0.19	0.01	0.09	0.03	0.03	0.03	0.29	0.94	0.45	0.48	0.16	0.08	0.96	0.34	0.37	0.21
Castanea	0.86	2.26	1.43	1.42	0.35	0.02	0.07	0.02	0.03	0.02	0.55	1.64	1.13	1.07	0.30	0.08	1.12	0.23	0.32	0.29
Conestoga	4.26	9.26	6.96	6.91	1.31	0.02	0.26	0.03	0.07	0.06	2.03	8.95	6.28	6.12	1.74	0.06	3.16	0.61	0.75	0.62
Danville	0.55	2.63	0.86	1.02	0.46	0.02	0.22	0.02	0.06	0.05	0.04	1.15	0.53	0.53	0.27	0.13	2.02	0.28	0.44	0.40
Dromgold	1.00	3.01	1.58	1.70	0.56	0.02	0.10	0.02	0.03	0.02	0.72	2.16	1.26	1.29	0.41	0.03	1.70	0.21	0.38	0.48
Hershey	2.68	6.31	3.89	3.94	0.99	0.02	0.10	0.05	0.05	0.03	1.69	5.58	3.65	3.46	1.13	0.03	1.45	0.35	0.42	0.34
Hogestown	2.73	5.08	3.88	3.88	0.71	0.02	0.09	0.03	0.04	0.02	1.92	4.89	3.50	3.47	0.92	0.08	0.88	0.31	0.37	0.26
Jersey Shore	0.43	1.38	0.72	0.73	0.23	0.02	0.08	0.02	0.03	0.02	0.22	0.71	0.46	0.45	0.12	0.04	1.00	0.18	0.25	0.24
Karthaus	0.37	1.53	0.69	0.71	0.29	0.02	0.09	0.03	0.04	0.02	0.21	0.59	0.37	0.38	0.11	0.01	1.03	0.18	0.29	0.27
Lewisburg	0.31	1.65	0.73	0.80	0.32	0.02	0.12	0.02	0.03	0.02	0.19	1.06	0.48	0.54	0.22	0.01	1.17	0.16	0.23	0.27
Manchester	1.27	5.29	2.31	2.45	0.87	0.02	0.63	0.05	0.08	0.13	0.79	3.40	1.73	1.79	0.66	0.13	2.18	0.42	0.58	0.47
Marietta	0.74	2.33	1.29	1.30	0.38	0.02	0.24	0.03	0.04	0.04	0.16	1.71	0.86	0.90	0.30	0.11	1.19	0.30	0.37	0.24
Martic Forge	3.50	10.09	7.82	7.51	1.57	0.02	0.47	0.05	0.11	0.13	1.49	9.58	7.23	6.59	2.19	0.04	2.18	0.67	0.87	0.65
Newport	0.82	2.54	1.44	1.54	0.45	0.02	0.09	0.02	0.03	0.02	0.40	2.02	1.18	1.19	0.36	0.35	1.13	0.23	0.32	0.27
Penns Creek	0.77	2.52	1.49	1.44	0.41	0.02	0.14	0.02	0.03	0.03	0.41	1.46	1.00	1.02	0.34	0.03	1.47	0.24	0.39	0.37
Saxton	1.20	2.84	2.10	2.12	0.38	0.02	0.11	0.03	0.04	0.02	0.89	2.41	1.58	1.69	0.42	0.02	1.12	0.32	0.39	0.28
Towanda	0.42	1.39	0.78	0.82	0.25	0.02	0.10	0.03	0.04	0.02	0.04	1.06	0.42	0.46	0.25	0.14	0.88	0.32	0.32	0.15
Wilkes-Barre	0.45	1.78	0.88	0.95	0.35	0.02	0.13	0.04	0.05	0.03	0.08	1.10	0.50	0.46	0.26	0.11	1.16	0.41	0.44	0.28
Richardsmere	4.73	9.11	7.05	7.09	1.31	0.02	0.23	0.05	0.07	0.07	3.13	9.38	6.44	6.50	1.54	0.18	1.42	0.50	0.58	0.32

Table B3. Dissolved Nitrogen Species Summary Statistics of Samples Collected During 2010, in mg/L

Station	Dissolved Nitrogen					Dissolved Ammonium					Dissolved Nitrate plus Nitrite					Dissolved Organic Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.61	1.47	0.89	0.95	0.22	0.01	0.12	0.06	0.06	0.04	0.26	1.16	0.50	0.56	0.25	0.18	0.64	0.31	0.33	0.13
Cohocton	0.94	1.75	1.25	1.36	0.26	0.01	0.15	0.03	0.04	0.04	0.51	1.48	0.88	0.92	0.31	0.17	0.77	0.37	0.39	0.15
Conklin	0.42	0.92	0.59	0.58	0.14	0.01	0.08	0.03	0.03	0.02	0.07	0.49	0.31	0.32	0.10	0.06	0.46	0.22	0.23	0.11
Smithboro	0.55	1.02	0.68	0.73	0.17	0.01	0.08	0.03	0.04	0.02	0.23	0.86	0.41	0.44	0.16	0.09	0.55	0.19	0.25	0.15
Unadilla	0.53	1.03	0.69	0.73	0.14	0.01	0.09	0.02	0.03	0.03	0.29	0.93	0.45	0.47	0.16	0.08	0.40	0.19	0.23	0.09
Castanea	0.79	1.80	1.34	1.28	0.30	0.02	0.07	0.02	0.03	0.01	0.55	1.64	1.12	1.06	0.30	0.06	0.38	0.15	0.18	0.09
Conestoga	3.13	9.24	6.73	6.64	1.57	0.02	0.23	0.03	0.06	0.05	2.03	8.95	6.27	6.08	1.73	0.13	1.04	0.45	0.51	0.26
Danville	0.39	1.82	0.73	0.83	0.31	0.02	0.20	0.03	0.05	0.05	0.04	1.13	0.53	0.53	0.27	0.03	0.99	0.20	0.25	0.19
Dromgold	0.92	2.24	1.59	1.52	0.37	0.02	0.09	0.02	0.03	0.02	0.72	2.18	1.26	1.28	0.41	0.04	0.50	0.17	0.21	0.15
Hershey	2.19	6.11	3.73	3.77	1.10	0.02	0.10	0.05	0.05	0.02	1.69	5.58	3.62	3.45	1.13	0.06	0.51	0.26	0.27	0.15
Hogestown	2.22	5.08	3.88	3.74	0.85	0.02	0.08	0.02	0.03	0.02	1.94	4.91	3.50	3.47	0.92	0.08	0.51	0.25	0.24	0.13
Jersey Shore	0.31	0.90	0.58	0.60	0.14	0.02	0.07	0.02	0.03	0.01	0.22	0.71	0.46	0.45	0.12	0.07	0.30	0.12	0.13	0.07
Karthaus	0.33	0.74	0.56	0.54	0.14	0.02	0.09	0.03	0.04	0.02	0.20	0.61	0.37	0.38	0.12	0.01	0.27	0.14	0.13	0.07
Lewisburg	0.31	1.27	0.68	0.71	0.24	0.02	0.12	0.02	0.03	0.02	0.19	1.07	0.49	0.53	0.22	0.03	0.46	0.14	0.16	0.10
Manchester	1.20	4.71	2.16	2.29	0.79	0.02	0.63	0.05	0.08	0.13	0.78	3.42	1.74	1.79	0.66	0.01	1.58	0.39	0.42	0.30
Marietta	0.40	1.80	1.07	1.09	0.30	0.02	0.07	0.02	0.03	0.01	0.16	1.69	0.87	0.89	0.30	0.05	0.31	0.17	0.17	0.06
Martic Forge	2.56	9.66	7.80	7.18	1.87	0.02	0.43	0.04	0.10	0.12	1.49	9.60	7.23	6.57	2.20	0.04	1.07	0.68	0.56	0.33
Newport	0.78	2.51	1.37	1.40	0.37	0.02	0.08	0.02	0.03	0.01	0.40	2.01	1.17	1.18	0.36	0.05	0.57	0.17	0.19	0.10
Penns Creek	0.75	1.68	1.34	1.29	0.29	0.02	0.13	0.02	0.03	0.03	0.41	1.46	0.98	1.01	0.34	0.03	0.57	0.23	0.24	0.14
Saxton	1.20	2.82	1.97	2.03	0.40	0.02	0.08	0.03	0.03	0.01	0.89	2.41	1.58	1.68	0.42	0.06	0.90	0.25	0.32	0.20
Towanda	0.24	1.26	0.73	0.73	0.25	0.02	0.08	0.03	0.03	0.02	0.04	1.05	0.42	0.46	0.25	0.08	0.54	0.22	0.25	0.12
Wilkes-Barre	0.38	1.32	0.76	0.76	0.26	0.02	0.09	0.04	0.04	0.02	0.08	1.09	0.50	0.46	0.25	0.07	0.48	0.24	0.26	0.14
Richardsmere	4.28	9.12	6.90	6.90	1.31	0.02	0.21	0.05	0.07	0.06	3.05	8.84	6.37	6.38	1.46	0.09	1.06	0.51	0.51	0.22

Table B4. Phosphorus Species and Total Suspended Solids Summary Statistics of Samples Collected During 2010, in mg/L

Station	Total Phosphorus					Dissolved Phosphorus					Orthophosphorus					Total Suspended Solids				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	0.027	0.587	0.086	0.130	0.152	0.013	0.087	0.034	0.040	0.023	0.005	0.074	0.022	0.028	0.019	2.0	1380	8	142	327
Cohocton	0.014	1.040	0.058	0.110	0.230	0.007	0.045	0.026	0.026	0.013	0.005	0.041	0.013	0.016	0.011	1.4	1040	15	76	235
Conklin	0.015	0.139	0.050	0.054	0.033	0.008	0.028	0.015	0.016	0.006	0.005	0.015	0.008	0.008	0.003	3.3	101	19	30	26
Smithboro	0.019	0.324	0.057	0.072	0.068	0.010	0.027	0.020	0.019	0.006	0.005	0.025	0.011	0.013	0.006	1.3	349	19	45	79
Unadilla	0.012	0.255	0.030	0.056	0.058	0.006	0.036	0.011	0.014	0.008	0.005	0.023	0.008	0.009	0.005	2.1	205	10	34	50
Castanea	0.015	0.325	0.028	0.058	0.086	0.010	0.029	0.011	0.015	0.007	0.010	0.021	0.010	0.012	0.003	5.0	344	8	40	86
Conestoga	0.036	1.492	0.164	0.250	0.299	0.014	0.530	0.105	0.148	0.122	0.010	0.460	0.097	0.121	0.102	5.0	1266	10	86	240
Danville	0.025	0.779	0.050	0.114	0.160	0.010	0.104	0.021	0.033	0.029	0.010	0.085	0.015	0.027	0.026	5.0	1284	12	98	260
Dromgold	0.012	0.793	0.034	0.104	0.202	0.010	0.216	0.020	0.037	0.048	0.010	0.178	0.015	0.029	0.040	5.0	550	12	65	153
Hershey	0.021	0.396	0.060	0.093	0.098	0.015	0.081	0.036	0.039	0.020	0.010	0.060	0.026	0.029	0.014	5.0	302	8	46	79
Hogestown	0.010	0.248	0.044	0.079	0.082	0.010	0.071	0.021	0.028	0.019	0.010	0.054	0.016	0.021	0.014	5.0	294	10	48	74
Jersey Shore	0.010	0.172	0.015	0.046	0.058	0.010	0.018	0.010	0.011	0.002	0.010	0.010	0.010	0.010	0.000	5.0	170	6	36	57
Karthaus	0.010	0.197	0.018	0.043	0.051	0.010	0.010	0.010	0.010	0.000	0.010	0.010	0.010	0.010	0.000	5.0	228	16	47	65
Lewisburg	0.010	0.226	0.020	0.041	0.057	0.010	0.030	0.010	0.012	0.004	0.010	0.022	0.010	0.011	0.002	5.0	278	6	32	62
Manchester	0.032	0.559	0.160	0.193	0.128	0.029	0.214	0.129	0.119	0.055	0.014	0.193	0.108	0.098	0.048	5.0	354	16	59	92
Marietta	0.014	0.332	0.045	0.079	0.085	0.010	0.068	0.014	0.017	0.011	0.010	0.055	0.011	0.013	0.008	5.0	346	14	55	89
Martic Forge	0.028	1.703	0.177	0.455	0.573	0.017	0.839	0.108	0.226	0.254	0.016	0.752	0.089	0.194	0.225	5.0	940	24	146	266
Newport	0.010	0.329	0.038	0.069	0.085	0.010	0.069	0.019	0.024	0.016	0.010	0.054	0.015	0.019	0.011	5.0	350	8	39	79
Penns Creek	0.010	0.562	0.023	0.081	0.135	0.010	0.182	0.015	0.032	0.043	0.010	0.158	0.011	0.026	0.037	5.0	340	8	42	81
Saxton	0.010	0.300	0.030	0.063	0.079	0.010	0.064	0.015	0.019	0.014	0.010	0.031	0.010	0.014	0.006	5.0	270	8	47	79
Towanda	0.020	0.428	0.048	0.071	0.080	0.010	0.054	0.020	0.022	0.010	0.010	0.054	0.014	0.017	0.009	5.0	624	11	52	113
Wilkes-Barre	0.018	0.492	0.050	0.122	0.135	0.010	0.038	0.019	0.019	0.007	0.010	0.029	0.013	0.014	0.005	5.0	582	16	117	177
Richardsmere	0.028	0.516	0.099	0.138	0.135	0.015	0.279	0.065	0.086	0.075	0.010	0.216	0.049	0.066	0.062	5.0	212	6	33	61

Table B5. Flow, Total Organic Carbon, Total Kjeldahl, and Dissolved Kjeldahl Summary Statistics of Samples Collected During 2010, in mg/L

Station	Flow (cfs)					Total Organic Carbon					Total Kjeldahl Nitrogen					Dissolved Kjeldahl Nitrogen				
	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	270	39,254	1,672	8,650	11,931	2.40	7.80	4.10	4.46	1.53	0.21	3.65	0.48	0.74	0.78	0.19	0.66	0.37	0.39	0.14
Cohocton	67	6,349	483	1,530	1,838	2.60	11.30	4.80	5.44	2.21	0.22	4.01	0.71	0.98	1.01	0.22	0.86	0.41	0.43	0.16
Conklin	650	23,501	5,853	7,697	6,432	1.60	6.10	3.40	3.47	1.10	0.10	1.18	0.33	0.40	0.26	0.10	0.53	0.25	0.26	0.12
Smithboro	1,015	68,147	11,104	17,479	16,994	1.70	5.70	3.65	3.58	1.09	0.12	5.58	0.32	0.66	1.18	0.12	0.62	0.20	0.29	0.16
Unadilla	184	5,703	1,145	1,729	1,545	1.50	6.70	3.30	3.63	1.29	0.10	1.05	0.36	0.40	0.23	0.10	0.47	0.20	0.26	0.11
Castanea	213	9,900	813	2,824	3,323	1.22	9.56	1.98	2.93	2.56	0.10	1.19	0.26	0.35	0.30	0.08	0.42	0.17	0.21	0.09
Conestoga	146	10,612	625	1,441	2,487	1.00	15.50	3.01	3.93	3.00	0.03	3.37	0.66	0.79	0.67	0.03	1.11	0.49	0.55	0.30
Danville	1,734	129,065	12,050	29,882	34,807	0.50	13.30	2.97	3.68	2.70	0.17	2.10	0.35	0.49	0.41	0.05	1.07	0.28	0.32	0.22
Dromgold	36	10,288	240	1,440	2,556	0.93	13.24	2.59	3.70	3.47	0.05	1.80	0.23	0.41	0.50	0.06	0.57	0.19	0.24	0.16
Hershey	105	5,406	879	1,553	1,696	1.10	10.70	2.27	3.14	2.32	0.08	1.53	0.38	0.48	0.35	0.10	0.54	0.33	0.32	0.16
Hogestown	147	7,724	844	1,884	2,201	1.10	8.37	2.76	3.51	2.26	0.10	0.93	0.34	0.41	0.28	0.10	0.55	0.28	0.28	0.14
Jersey Shore	670	133,515	8,388	30,987	39,268	0.85	7.47	1.84	2.43	1.84	0.06	1.02	0.20	0.28	0.24	0.09	0.32	0.14	0.16	0.07
Karthaus	241	32,639	3,857	8,298	9,738	0.96	9.30	1.91	3.08	2.67	0.04	1.10	0.22	0.33	0.28	0.04	0.31	0.17	0.17	0.08
Lewisburg	879	137,717	6,774	27,604	36,715	0.50	8.00	1.75	2.29	1.78	0.06	1.21	0.19	0.27	0.26	0.06	0.49	0.17	0.18	0.10
Manchester	52	11,850	372	1,738	2,840	0.50	11.70	4.24	4.99	2.63	0.15	2.81	0.45	0.67	0.58	0.03	2.21	0.42	0.50	0.42
Marietta	4,701	315,658	31,042	83,788	96,351	1.48	7.30	2.93	3.24	1.51	0.16	1.26	0.36	0.41	0.24	0.09	0.36	0.19	0.20	0.06
Martic Forge	60	2,832	235	498	704	1.06	15.70	2.49	4.58	4.37	0.02	2.65	0.72	0.99	0.77	0.02	1.50	0.71	0.66	0.42
Newport	739	48,195	3,119	11,491	15,081	1.00	8.20	2.62	3.19	1.82	0.05	1.20	0.26	0.35	0.28	0.01	0.65	0.19	0.22	0.12
Penns Creek	75	8,473	400	1,946	2,477	1.05	11.60	2.51	3.54	3.07	0.05	1.61	0.26	0.42	0.39	0.05	0.70	0.25	0.27	0.16
Saxton	86	20,909	735	2,995	5,153	1.13	10.12	2.58	3.48	2.30	0.04	1.20	0.34	0.43	0.29	0.08	0.98	0.28	0.35	0.21
Towanda	1,047	107,672	11,777	22,821	26,501	0.50	9.90	3.13	3.35	1.62	0.16	0.94	0.34	0.36	0.16	0.10	0.59	0.24	0.28	0.12
Wilkes-Barre	1,739	119,788	14,400	36,591	38,826	1.00	10.40	3.14	3.98	2.46	0.13	1.26	0.44	0.49	0.29	0.11	0.51	0.28	0.30	0.14
Richardsmere	46	8,239	272	822	1,882	1.51	8.00	2.59	3.25	1.75	0.25	1.60	0.59	0.66	0.35	0.15	1.23	0.56	0.58	0.26